LIFE STORIES OF THE

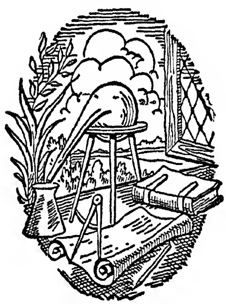
Great Inventors

LIFE STORIES OF THE

Great Inventors

By HENRY THOMAS AND
DANA LEE THOMAS

Illustrations by
GORDON ROSS
and
CAMPBELL ROSS



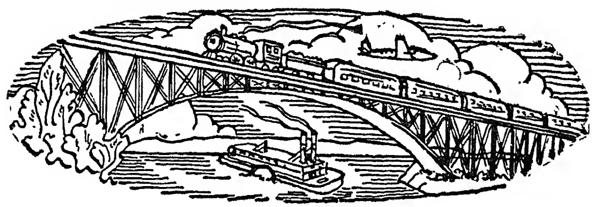
Halcyon House
GARDEN CITY, NEW YORK

PRINTED IN THE UNITED STATES
AT
THE COUNTRY LIFE PRESS, GARDEN CITY, N.Y.

FIRST EDITION

Contents and Illustrations

Introduction



THE scientists are the expounders, and the inventors are the practitioners, of knowledge. The scientists ascertain the secret powers of the universe, and the inventors exploit these powers for our human needs. The inventors, therefore, are among the most important of our pioneers. For it is due to their patient labors that our impatient human race has been able to acquire the tools of a happier, healthier and more efficient existence. From the unknown genius who fashioned the first wheel, down to Edison and Diesel and Marconi and Baird, the engineers of better communication, speedier locomotion and a wider vision have helped to make the world more compact and humanity more closely akin. The inventors are the cooperators of our multitudinous groping toward the light.

And their cooperation has been twofold. Their inventions have been bestowed as a common gift to all mankind, and their experiments have been conducted upon a common basis of scientific reciprocity throughout the world. A great invention is not the result of individual and isolated effort; it is rather the culmination of a wide and varied exchange of ideas and labors and tools.

To be sure, we may find here and there an egocentric inventor who refuses to acknowledge his indebtedness to other inventors. But men of this type are the exception rather than the rule. The majority of the great inventors are simple and modest men of genius, humble workers who are eager to accept the assistance of their fellow-workers, and to repay it—with gratitude if no other means are available. Most of the inventors whose biographies are included in this book are such men—free-minded and free-hearted adventurers of the spirit. And it is this spiritual adventure, often accompanied by physical distress, that has turned their biographies into sagas of inspiration, ambition, struggle, suffering, disappointment, and ultimate success.

The stories of their lives are only a chapter in the story of the practical progress of science.

The inventions of these men—of all the great inventors in the past—are but the prelude to the even greater inventions of the future. It is useless to speculate as to the nature of these future inventions, just as it would have been useless for an ancient Greek or Roman to speculate as to the nature of television and the automobile and the photoelectric cell. But of this much we may be reasonably sure: the *inventiveness* of the human mind will keep pace with the *hunger* of the human mind, the hunger for a closer observation into the mystery of the world and a friendlier collaboration between man and man.

H.T.
D.L.T.

JOHANN GUTENBERG

Important Dates in the Life of Johann Gutenberg

C.1398—Born, Mainz, Germany.

1438—Entered into his first partnership to practice the art of printing.

1450—Received financial help to build a press for the printing of the Bible in Latin.

1456—Latin Bible, first book known to have been printed with movable type, produced in partnership.

1465—Appointed to the court of the Archbishop of Mainz.

C.1468—Died, Mainz, Germany.

Johann Gutenberg

1398?–1468?

THE IDEA OF PRINTING from clay tablets and from wooden blocks dates back to the pre-Christian era. It was known probably to the Assyrians about 700 B.C., and certainly to the Chinese about 50 B.C. But the invention of printing from *movable type*—that is, from the rearrangement of single letters and characters into various words—is only 500 years old.

And when the modern art of printing was first introduced to the world (about 1450), many a pious soul was astounded and shocked at the "Devil's work." A Parisian bookseller who sold two printed copies of the *Latin Grammar* of Donatus was thrown into jail as a Devil's disciple. "For only a dealer in the black art can produce two copies that are exactly alike."

II

THERE WERE THOSE who credited the invention of printing not to Johann Gutenberg but to Laurens Coster, a native of Haarlem in the Netherlands. Coster was said to have printed (in 1423) sentences from letters carved out of beech-bark, and to have

subsequently replaced his wooden type with letters of lead and of pewter. This claim, however, is now generally disregarded; for there is in existence today not a single printed document that can be ascribed to Coster. Johann Gutenberg is almost universally recognized as the father of the "magic art of winged words."

Johann Gutenberg came of a patrician family whose surname was Gensfleisch. They adopted the name Gutenberg from the estate on which they lived. Johann's father, Friele zum Gutenberg, was the treasurer of the city of Mainz. This city had once enjoyed a reputation as a prosperous trading center on the Rhine. But the Black Plague, added to the incessant quarrels between the patricians and the guilds, had reduced the city to a down-at-the-heel township of 6,000 souls. In such a community the Gutenbergs, though far from wealthy, were regarded with envy by the even poorer members of the various guilds. And these poorer citizens were ever on the watch to dispossess "the rich" and to take over the government of the city for themselves.

It was in this atmosphere that Johann spent the early days of his life. A grounding in Latin at school, a training at home to stay away from the workers and the other "riff-raff" of the town, and a thorough indoctrination in the commandments of the Holy Book—these, in the main, formed the substance of his childhood education.

These, and two other important influences—the inconvenience of waiting for his textbooks, and the pleasure of playing with his picture blocks.

For in those days the textbooks, like all other publications, had to be copied by hand. A long and laborious and expensive job. Education was not only costly, but slow. And a pupil with a nimble mind like Gutenberg's found it tedious to wait for a new book when he had mastered the old.

To while away the time, he played with the picture blocks at his home. His father had sent to Italy for these blocks—pictures carved out of wood and impressed, by means of ink, on parch-

ment or paper. Figures of kings and queens and knaves for playing-cards, and representations of episodes and scenes from the Bible. As he looked at his Biblical pictures, an interesting idea occurred to him. Why not collect a number of these pictures, and sew them together into a book? And then print, from the same blocks, another set of pictures and another and another, and bind every set of pictures into a separate book?

As he grew older, the idea of printing a book from *picture-blocks* developed into a more elaborate idea—to print a book from *word-blocks.* One day, as he watched a scribe copying his Donatus grammar, he said: "I think you could save time, Sir, if you would carve the pages of this book into blocks, like pictures, instead of copying them out on parchment."

"But I'm not a carver, my son. I'm a writer . . . Besides, I'm a great believer in tradition. What was good enough for my ancestors is good enough for me."

Shortly after this interview, Johann startled his father with a request to apprentice him to a wood-carver. "But carving is a trade for the lower classes, Johann. Don't forget that you are a patrician!"

A youngster with strange ideas and a stubborn mind. "God meant the patricians, too, to work with their hands." Perhaps the child was right. The way things were going in the topsy-turvy world of 1415, many a Mainz patrician might soon be reduced to the indignity of working for a livelihood. Perhaps a refined sort of occupation mightn't be such a bad idea for Johann. Not wood-carving, however. Too much like carpentry—a trade suited only to the calloused sensibilities of the mob . . .

And then an idea struck Friele Gutenberg. If the boy *insisted* on carving, let him work in the medium of silver and gold. Aristocratic metals for a patrician child. And so he apprenticed Johann to the engraver at the city mint. Right close to the treasury, where he himself was employed, and where he could keep an eye on the youngster.

Johann liked the work. It was even better than carving on wood-blocks. The figures and the letters were smaller, and the engraver's touch had to be ever so much more delicate. The minting of money was merely the printing of pictures in miniature. First, the design for one of the sides of the coin was modeled in wax by an artist. And then the engraver chiseled the design into a piece of soft steel, hammered the lettering of the coin into the edge of the steel, and hardened the die of the soft metal by heating it in a flame.

In the meantime, the design and the die for the other side of the coin were prepared in exactly the same way.

And now the workers were ready for the stamping of the coin. They placed a disc of the precious metal between the two dies—a sandwich of silver or gold between two slices of steel—laid the "sandwich" down under a hammer, and pounded the dies together until their lettering and design became imprinted upon the coin.

Only a few letters on either side, and only a small design. So much neater than the page-long combination of pictures and words that were carved out in the unwieldy wood-blocks of the playing-cards.

The selfsame continuous succession of pictures and words—bound always together in the solid block and never allowed to be separated . . . Suppose you wanted to substitute one word for another, or to rearrange the design. It just couldn't be done. The block was a single unit.

But so was the coin, a single unit. Yet there were only a few letters on the coin. What if you had only a few letters on a block, and another block with only a few letters, and still another? Or still better—strange that nobody had ever thought of it before him!—what if you had only *a single letter* on each block? Then you could carve out these letters on as many blocks as you needed for the printing of a sentence—a page—an entire book!

This idea became indelibly impressed upon his mind as he

kept working at the mint. When he came home at night, he began to experiment with the idea on little squares of wood. Single letters for each square, and several sets of letters for the entire alphabet. What a fascinating game, arranging these individual letters into all sorts of word-combinations!

But what a laborious job, cutting out all these letters over and over again! Not only laborious, but—from a practical standpoint—almost useless. For the wood kept splintering and splitting as you tried to impress the letters upon sheets of paper. You could avoid this breaking of the type, of course, if you carved the letters out of metal instead of wood. But what a job *that* would be!

And then a simpler solution to the problem occurred to him. One day he was watching a jeweler at his work. The man was reproducing a metal brooch. A most interesting process. The jeweler opened a casting-box, filled the two halves with fine damp sand, placed the original brooch on the surface of the sand in one half of the box and then shut the other half tightly down upon the first. In this way, an exact impression of the brooch was hollowed out in the damp sand. He now took out the brooch, poured melted metal into the hollow impression in the sand, and thus fashioned an exact duplicate of the original model.

As Gutenberg watched this operation, he realized that he could do with model letters just what this jeweler was doing with a model brooch. Instead of carving separate wood-blocks for all the repetitions of the various letters, he would make one block for each letter and then sand-cast all the duplications of these letters in metal type.

And this is how the invention of printing came about.

III

BUT THE IDEA was still in its embryonic stage. In order to perfect himself in the art of shaping small and delicately-rounded objects, like the letters of the alphabet, he went to work for the jeweler.

He became an expert in the cutting and the polishing of precious stones.

A few years of this delicate carving in jewels, and then his work was unexpectedly interrupted. The guild members of Mainz had rebelled against the patricians and had taken over the government. They passed "defensive" laws against the "idle rich" and expelled a number of their ringleaders from the city. Among those exiled was Johann Gutenberg.

Thirty years old now, and almost penniless. He threw his few belongings into a bundle and moved to the more hospitable city of Strasbourg, about a hundred miles away.

Here he found work in his chosen field of jewel-cutting and devoted his evenings to his experiments in the carving and the casting of movable type.

In order to defray the expenses of his experiments, he tried to collect his share of the Gutenberg property—his parents were now dead—from the Mainz officials who had confiscated it. But in vain. They had the law on their side, because it was they who *made* and *administered* the law. And so he was obliged to work on, with insufficient funds and a bitter heart.

But there were friends in the city who gave him their moral if not their financial support. One of these inspiring friends was the Bishop of Strasbourg. They were building the cathedral at the time. A long and costly and often discouraging job. Yet the bishop had an undying faith in the success of the enterprise. "We will go on with the building, stone by stone, and prayer by prayer, until the uppermost of the towers has reached into the sky." He, too, Johann realized, was building a cathedral for the future. A monument of human aspiration based upon the printed word. And he too, God willing, would persist in spite of all obstructions until the work was done.

And the obstructions came in upon him thick and fast. A love affair with an aristocratic young lady, a quarrel when he refused to give up his "crazy invention" for her sake, and a lawsuit

against him for breach of promise. He won the case—and found himself almost immediately involved in a maze of other lawsuits. One of these was against the city clerk of Mainz, who was visiting Strasbourg and who was arrested at Gutenberg's demand. "I'll release the prisoner if he will promise to release my funds." The city clerk readily gave his promise—and as readily forgot it when he returned home. At about the same time, Gutenberg was sued by a cobbler, Schotten Lawel, for "defamation of character" because, when the cobbler had testified against him in his breach of promise trial, Gutenberg had called him a liar. Gutenberg lost the case and was compelled to pay a fine.

A stormy character, whose slender funds were being constantly dissipated by the storm. Yet he kept doggedly on with his dream. He found three partners who offered to supply him with capital for the establishment of a printing shop. One of the partners died, and the others tried to steal Gutenberg's ideas and his press. Another lawsuit—long and anxious days of hunger and dejection and despair—and finally the courts decided in his favor. But the influential citizens of Strasbourg had decided against him. Who was this "foreigner" who had brought so much disturbance into their midst? One of the defendants in his lawsuit against the stealing of his invention was the sheriff of Strasbourg. How dared a "mere Maintzer" to accuse a "respectable Strasbourger" of dishonesty? Let the trouble-maker get out of their city, they insisted. And let him get back where he belonged.

A good opportunity to return to Mainz. There had been another revolution in that city, and the patricians were again in the saddle. He came home with renewed energy, but with no prospect of recovering his confiscated estate. It had been frittered away in his everlasting lawsuits to regain it, until now there was nothing left.

He formed another partnership to set up a printing shop. His new partner, a goldsmith by the name of Johann Fust, offered to

finance the printing of the Donatus grammar and, later, of a much more ambitious work—the Bible.

"Before we undertake the Holy Book," Gutenberg cautioned his partner, "I shall have to make many improvements in my type. We must have nothing but the best for the word of God."

"You are right," said Fust. "Perfection above all. I have the money, so we can both afford the patience."

Again Gutenberg trusted a friend—only to be doomed to disappointment again.

IV

THE PRINTING of the Donatus was a great success. This Latin grammar was being used in many schools throughout Europe; and within a short time, the little book of twenty-eight pages went into fifteen editions.

But the printing of the Bible was quite another matter. It was to be a book of a thousand pages, two columns to a page—a colossal expenditure of time and money and metal and type. And the designing and the casting of the type had to be constantly improved so as to stand up against the wear and tear of the presses and to offer a uniform and even impression upon the page. At first he cut each letter out of a piece of wood, molded it in brass by the sand-casting method, touched it up to an equal height with the other letters, and "punched" it with a hammer into a piece of lead until the lead received a clear impression of the letter. This "impressed" piece of lead became the "matrix"—or "mother"—of all the duplicate copies of the letter that were to be cast in it. As time went on, however, he gradually discarded the wood-carving and the sand-casting process. Instead, he now carved the letter directly out of soft steel, then alternately heated and plunged the steel into cold water until it became hard enough to be used as a punch. And then, by dint of still further experimentation, he discovered that the letter of tempered steel could

be hammered into a metal that was harder than lead. And so he changed the "mother-metal"—that is, the matrix—from lead to copper.

And thus, trying to perfect the vehicle for "the divine message of God," he exhausted the human patience of his partner. It was now two years after the formation of their partnership, and Gutenberg had nothing more substantial to show than a heap of discarded type-models. "When are you going to show me some real results?" asked the irate goldsmith.

"In God's good time, my friend."

"Yes, but not in *my* time, it would seem. Nor in *your* time, either."

Another year passed, and no apparent progress. Gutenberg's partner was furious. "I can do better myself, hiring my own men and superintending my own ideas." And so, disregarding the fact that the original idea of printing was not his but Gutenberg's, he confiscated the machinery that Gutenberg had made, stole his invention and, adding insult to injury, sued the inventor for all the money invested in the enterprise to date.

Gutenberg was now fifty-six years old. When he received the summons to the court, he almost collapsed.

At the trial he pointed out the many difficulties that had occasioned the delays in the printing of the Bible. But, in the ears of the judges, the voice of Gutenberg had a less persuasive sound than the jingle of coin. They decided that Johann Fust had invested his money in the expectation of an early return, and that he had a legal right to the fulfilment of his expectation. They therefore issued an order that the shop, with all its equipment, belonged to Fust, and that Gutenberg had no legal claim either to his ideas or to his work.

A dispossessed and penniless outcast on the threshold of old age.

V

JOHANN FUST and his associates completed the printing of the Bible, with not a word of credit to Gutenberg for the invention that had made the printing possible. As a bitter sequel to the whole business, Gutenberg received a letter of congratulations from the Bishop of Strasbourg who, having seen a copy of the Bible, had concluded that it was the publication of his friend. "I thank the Lord for having guided you to the realization of your dream."

Gutenberg smiled. A dream turned into a nightmare, so far as his own fortunes were concerned . . .

But Gutenberg was a fighter, even now that his strength was almost gone. He scraped together a few gulden, opened a little shop, sent for the type he had stored away in Strasbourg, and set to work printing a Bible of his own. Slow, starving, heartbreaking work. But the glowing words of the text served as a guide to his trembling fingers.

And finally, at the age of sixty-one, he finished the job. Larger type than that of the Fust Bible, and less lines to the page. But more readable, therefore, and more pleasant to the eye.

And now, the glory of an unclouded sunset to Gutenberg's life. Printing presses were set up everywhere, and young students were sent to him from a number of universities to receive instruction in the "magic art of spreading wisdom among men." And best of all, perhaps, an appointment to the personal staff of the Archbishop of Mainz. A great honor, and a sufficiency of funds to give him the leisure for working without the fear of starvation.

Not much time, though, left for his work. Sixty-five now. Yet he managed to print one other important book—the *Catholicon,* a Latin dictionary. A bridge of communication between the minds of men. For Latin was the universal language of the learned—the common speech of the civilized world. And Guten-

berg, the uncultured cutter of metals and stones, was determined to bestow upon the world this traffic of ideas over a pavement of printed words.

A thought to exalt the humble, and to humble the exalted. It was in this spirit that he dedicated the *Catholicon* to "the Most High, at whose nod the tongues of infants become eloquent, and who oftentimes reveals to the lowly that which he conceals from the wise."

JAMES WATT

Important Dates in the Life of James Watt

1736—Born, Greenock, Scotland.

1755—Apprenticed to an instrument maker in London.

1757—Appointed mathematical instrument maker to the University of Glasgow.

1769—Took out first patent on his steam engine.

1763—Married his cousin, Margaret.

1775—Organized business to manufacture his steam engines. Married for the second time.

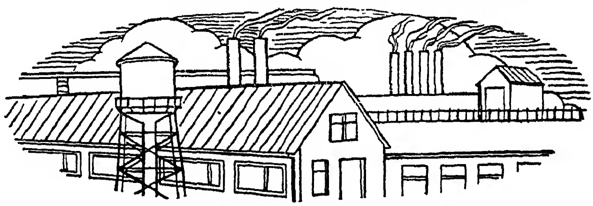
1780—Patented a press for copying manuscripts.

1800—Retired from business. Turned over affairs to his sons.

1819—Died, Heathfield Hall, near Birmingham, England.

James Watt

1736–1819



THE LIFE OF JAMES WATT demonstrates the proposition that genius is an infinite capacity for taking pains. Owing to his parents' poverty, he was unable to get an adequate academic education. Yet, through his sheer persistence, he kept fighting for his knowledge—against want, discouragement, and disease—until he became not only a supreme inventor but a superior exponent of the liberal arts.

And he picked up his liberal knowledge as a result of his eagerness to advance his scientific information. One day, for example, he heard of a German book which dealt with the processes and the machinery of mining in the Hartz Mountains. He secured the book and set himself to the study of the German language in order that he might be able to read the text in the original. "A translation may fail to convey the exact picture of the scientific data as presented in the book."

In a similar way, and for similar reasons, he learned French and Italian. And—so keen was his intellectual curiosity—whenever he learned a new language for his scientific studies, he acquainted himself thoroughly with the literature of that language

and with the thoughts of the people who spoke it. So that he became not only an interpreter of the laws of *nature,* but an observer of the principles of *human nature.* In the process of his inventions, this canny son of Scotland had developed an amazing faculty for marshalling facts, understanding motives, and making friends.

But he had a very poor faculty for making money. One of the world's greatest inventors, he was one of its poorest business men. He could master everything but the art of turning his genius into cash. As a result of his inability to recognize his value, he lived for the greater part of his life on the edge of disaster. He suffered continually from ill health and low spirits. "I have much contrived," he wrote to a friend (1769), "and little executed . . . I am continually plagued with headaches and heartaches . . . How much I *could* accomplish with less anxiety and better health!"

And how much he *did* accomplish with all his illnesses and frustrations and cares! There are some substances that are destroyed in the fires of adversity; others, on the contrary, are only hardened by the flame. Jamie Watt's character was made out of that sterner stuff.

II

His FATHER was a builder of ships, and his mother a builder of character. Business reverses had compelled the family, shortly after Jamie's birth, to move into Poverty Street. But they brought along with them their respectability. A young girl who visited their home remarked, upon her return to her mother, "Mrs. Watt is a braw, braw woman—and very ladylike. Why, she had *two candles* lighted on the table." A sign of regal splendor in the simple Scottish village of Greenock.

But for all her "regal splendor," Mrs. Watt was unable to send Jamie to school. He was too delicate to be thrown together with the "little roughnecks" of the neighborhood. She had lost several

of her children before Jamie was born; and, God willing, she would save *him* at least. And so she kept him at home, taught him to read and to write, and fed his imagination with the poetry and the romance of Scotland. Scarcely, it would seem, a training conducive to an inventive career. He remained, as a child, backward in the scientific studies—especially in arithmetic. But he had amazingly clever fingers—an inheritance from his paternal ancestry. And a mind eagerly attuned to the wonders of the world. A talent, his mother declared, directed toward artistic work. The making of pretty poems, perhaps, or the fashioning of useful tools.

And this artistic faculty of Jamie's was the amusement—and the dismay—of his grandparents. He paid them a visit at Glasgow—a change of scenery, the doctor said, that might do him good. At the end of a few days, however, they had to send him home. His tales of derring-do had kept them awake at night. His transformation of the furniture into the fortifications of his military exploits had turned the household into a battlefield. And his sudden ebullitions at the most unexpected moments—especially at mealtimes—had disorganized the entire routine of the family. "A little Vesuvius in eruption," his grandmother called him.

Yet at times he could sit quietly for hours—just thinking. At such times he was a shy, reserved and sensitive little soul—"a stranger and afraid in a world he never made." What in heaven's name, wondered his parents, can be going on in that peculiar little brain of his? Sometimes he would pick up his toys, break them into pieces, and rebuild the fragments into new toys. Plenty of opportunity to do that sort of thing. Not many toys, to be sure—his parents could rarely afford them. But many days of illness, when all he could do was to lie idly in bed and play with his fingers. "Jamie," remarked a friend of his father's, "has a fortune at his finger-ends."

A strange child—with his periods of overbubbling enthusiasm, making and breaking things with his fingers, or just dreaming

away his hours without any apparent reason or rhyme. One evening "he sat at the tea-table with his aunt, Mrs. Muirhead"—we are repeating the story as told by his cousin, Mrs. Campbell, who was present at the time. "James Watt," exclaimed his aunt, "I never saw such an idle boy! . . . For the last hour you haven't spoken a word—just taking off the lid of that kettle, putting it on again, holding now a spoon over the steam, watching it rise from the spout, and catching it as it gathers into drops of hot water. Aren't you ashamed to be wasting your time with such silly stuff? . . . Why don't you take a book, or run off and play like other boys?"

Couldn't learn to play like the other little boys. Too busy watching nature at her mysterious work. Observing the action of steam in the teakettle and the parade of the stars in the heavens, solving the Chinese puzzle of mathematical problems—he was at school now, and becoming quite adept at geometry—contriving original experiments in chemistry and in physics, and trying to master the abstract ideas of the mind as well as the concrete facts of nature. At fifteen he had read and re-read and digested Gravesend's *Elements of Philosophy,* and had startled his family with the production of an electrical machine of his own. "Perhaps the child is not so hopeless after all." His mind, to be sure, is adrift. But he does seem to be trying to get somewhere. A little more schooling, and maybe they will see the general tendency of his drift.

III

BUT BEFORE LONG his school days were over. His mother died (1753); his older brother, John, had gone to sea and had been shipwrecked; his father's business affairs had reached a low ebb; and Jamie Watt was compelled to go to work.

He went to live with his mother's family, the Muirheads, in Glasgow. This time it was no longer an erupting little Vesuvius

that came to distract them, but a sober young mechanic who was anxious to find work.

And his clever fingers came to his aid. He entered the service of an optician who, in addition to grinding glasses, repaired fiddles, tuned spinets, made fishing rods, upholstered furniture and offered to "fix or fashion anything useful to man."

And thus, at seventeen, James Watt became apprenticed to a jack-of-all-trades—and managed to master them all. "Never saw such amazing versatility in my life!" exclaimed his employer as he watched him at his work.

But the young apprentice found little satisfaction in his work. He wanted to become an expert in the making of mathematical instruments—a trade which required extraordinary skill and which found very few candidates who could live up to the requirements. It was a challenge to James Watt, and he was anxious to meet it.

"If you want anything hard enough, and keep on wanting it, the chances are you will get it." Through a relative of his mother's, Professor Muirhead, he was introduced to Dr. Dick, professor of science at Glasgow University. At the suggestion of Dr. Dick, he went to London where "you can get much better mechanical instruction than is possible here in Scotland."

A year's apprenticeship as an instrument maker in London, amazing progress, and considerable heartache. For he was compelled, during this period, to rely upon his father's support. It wasn't much—only $2 a week—but it irked him to strain his father's resources even to this trifling extent. "I long for the day when I can take care of myself and repay you for all you have done."

But taking care of himself wasn't such an easy matter. Before his year of apprenticeship was over, he wrote to his father that he had made "a brass sector . . . which is reckoned as nice a piece of . . . work as is in the trade." He applied for membership in the Glasgow Guild of Hammermen—and his application was re-

jected. A seven-years' apprenticeship was necessary as a qualification for membership in the Guild. Watt had learned his trade in one year. He was "too good to be true." He asked the Guild for permission to rent a small shop—"not for business but for scientific experiments." This request was also turned down. Here was one of the leading toolmakers in Scotland, forbidden to make tools!

At this juncture, his friends at the university came to the rescue. In accordance with the university charter, the faculty had supreme authority for assigning and accepting work within its campus. And so they gave him a workroom in one of the college buildings. Here he was at liberty, without the Guild's sanction, to make and to sell his instruments and to conduct his "strange but fascinating" experiments.

An uncultured layman, teaching beauty and precision to his educated peers. Like his first master, the Glasgow optician, he turned out all sorts of things—lenses, fiddles, flutes, guitars, fishing-tackle, quadrants, sectors, compasses, and, just to show his versatility, an occasional organ. "Watt," observed one of the professors at Glasgow, "knows most things and can make anything."

A young man who took infinite pains in everything he did. In order to make his musical instruments as perfect as possible, he thoroughly familiarized himself with the laws of harmony. By the time he had completed his first organ, "there was not a man in Britain who knew more of the science of music than James Watt."

His "magical" workshop had become the rendezvous of the college faculty. They marveled at his skill, and admired his modesty. Again and again he acknowledged his debt "to those who were all much my superiors, I never having attended college and being only a mechanic."

Yet many of the professors realized that the superiority lay not with them, but with the young mechanic. Even, at times, in their own specialized fields. "I had the vanity," wrote Professor Robi-

son, referring to one of his conversations with Watt, "to think myself a pretty good proficient in my favorite study—mathematical philosophy. I was therefore quite mortified at finding the youngster so much better acquainted with the subject than I myself."

But always he spoke to others in a tone of deference. His modesty, however, never descended to servility; it remained at all times on the high level of dignified respect. He was so anxious to acknowledge the good in others that he often overlooked his own good.

IV

It was through Professor Robison that Watt became interested in steam engines. The university at that time owned a Newcomen engine—a mechanism that had been purchased for experimental use in the natural philosophy department. It was a crude contraption of pipes and boilers and pistons that generated a maximum of sound and fury and a minimum of practical power.

The engine was a challenge to Watt's ingenuity. He began to read up on the subject and to experiment with various models built upon the principles of this machine. He made the models himself, using apothecaries' vials for boilers and hollowed canes for pipes. But the idea refused to work. Theoretically it seemed all right; but practically it resulted in failure after failure. Every time you started the piston, both in the original and in the models, there would be a few gasping strokes and then the power would sputter out.

But Watt never gave up. "Every obstacle," observed Professor Robison, "was to him the beginning of a new and serious study, and I knew he wouldn't quit until he had either discovered its worthlessness or had made something of it."

Infinite patience, assiduous application, inspired thought. *"The thing has worth, and I propose to make it work."*

And then came the clue to the final unleashing of the secret

power. In the course of his experiments, he had discovered the principle of latent heat. This principle, briefly stated, means that a tremendous amount of heat lies hidden in nature until it can be set mechanically free. Thus, for example, *one pound of steam* inserted into freezing water will bring *five pounds of the water* to a boiling point. In other words, a quantity of water converted into steam will release enough latent energy to bring five times its own weight of water into steam heat.

And now that the generating power of heat had been discovered, it was merely a matter of time—Watt insisted—before he would find a way to harness it to the service of man. Build an engine to capture all this latent energy so that as little of it as possible can escape, and then direct this energy to the pushing of a piston, the pumping of a mine or the turning of a wheel.

Easier said than done. It wasn't enough merely to harness the steam in the engine. It was necessary to regulate its power when released. And this release of the steam, both in the Newcomen engine and in Watt's early models, resulted in the loss of about four-fifths of its energy. This loss was due to the cooling of the cylinder during the action of the engine; and the cooling of the cylinder in turn was due to the fact that the piston, after its upward stroke, could not be sent to the bottom for another upward stroke without the injection of a stream of cold water. It was a long time before Watt discovered the second secret of the steam engine—how to *preserve* the latent heat in the cylinder after he had succeeded in *harnessing* it. The idea of this discovery came to him as he was walking on a Sabbath afternoon, in 1865. "I knew that in order to make a perfect steam engine it was necessary that the cylinder should be always as hot as the steam which entered it . . . Suddenly the idea came into my mind that as steam was an elastic body it would rush into a vacuum, and if a communication were made between the cylinder and an exhausted vessel it would rush into it, and might be there condensed without cooling the cylinder . . ."

Johann Gutenberg

James Watt

A simple idea—this separate condenser—once you happened to think of it. But it took infinite pains and patience for the preparation of the mind to *receive* this revolutionary idea. Years later, when publicly hailed as the conqueror of steam, he remarked that the contrivance of the condenser had just happened to occur to him. "There it was; somebody had to stumble upon it." But—as he failed to add in his modest way—it had to be somebody with the inventiveness and the tenacity of a James Watt.

The principle of the modern steam engine was now—to all practical purposes—complete. The condenser carried the steam into a separate vessel, leaving the cylinder uniformly hot. A circular piston kept pumping the steam through this cylinder, maintaining the cylinder at the same high temperature as the steam that entered it. In this way there was very little loss of the latent heat of the steam as it became transformed into the energy that "revolutionized the labor of the world."

V

MARRIAGE, INCESSANT TOIL, an unresponsive public, disappointments, headaches, heartaches, poverty, despondency, and the untimely death of his wife. He formed a partnership with Dr. Roebuck, founder and proprietor of the Carron Iron Works. But the venture brought only ruin to his partner. For invention and business remained at odds in the character of James Watt. "I would rather face a loaded cannon," he wrote, "than settle a disputed account or make a bargain." Engine after engine, though built upon a plan which was theoretically sound, refused to come up to specifications when put to practical use. Often it was the fault of the workmen. At times, as he was honest enough to admit, it was his own fault. A failure to tighten this or that joint—"my engine sniffs at many openings"; a misfit between piston and cylinder that resulted in the breakdown of the entire machine—"my old White Iron man is dead"; a thousand and one other

little oversights that resulted in leakage and loss of power. And always, when a customer complained, Watt agreed with the complaint. "My work, I know, is poor enough; but I am trying to make it better."

He was anxious, in short, not for profit but for perfection. He acknowledged his "intermediate failures and uncouth constructions" as the stepping stones toward the "faultless machine." But he was greatly disturbed at the inconveniences that his failures occasioned to other people. "You cannot conceive," he wrote to a friend concerning one of his imperfect machines, "how mortified I am with this disappointment . . . I cannot bear the thought of other people becoming losers by my schemes."

And the dissatisfaction of his customers with his earlier machines was not always due to a defect in the mechanism. When one of his better engines was completed, a number of scientists and mining experts were invited to inspect it. "All the West Country captains (of industry) were there to see the prodigy," he wrote. "The . . . horrible noise of the engine gave universal satisfaction . . . I once or twice trimmed the engine to end the stroke gracefully and to make less noise." Whereupon many of the observers expressed their displeasure at the "reduced efficiency" of the machine. "The noise," he whimsically observed, "seems to convey great ideas of its power to the ignorant, who seem to be no more taken with modest merit in an engine than in a man."

VI

But finally both the man and the engine were recognized at their true value. Another partnership—this time with a friend who had an amplitude of business ability as well as a sufficiency of funds—and Watt for the first time knew the happiness of a secure livelihood.

Another partner, and another wife. He was as happy in his second marriage as in his second business venture. His wife gave

him the necessary courage—and his partner, the necessary capital—for the perfection of his engine.

The business partnership developed into an ardent friendship. James Watt and Matthew Boulton took to each other from the start. Mr. Boulton, a manufacturer of Birmingham, was one of the founders of the modern idea of low prices through mass production. But he was a philanthropist as well as a business man. He employed only one class of apprentices—"fatherless children, parish wards and hospital boys"—and he maintained a home in which his apprentices were properly sheltered, fed and educated. But it was his head as well as his heart that induced him to accept the inventor as a partner. Watt needed a sponsor—and the sponsorship, he was convinced, would ultimately result in profit to the beneficiary and the benefactor alike.

And so it turned out. The firm of Boulton and Watt—the one "running his business like a romance" and the other "perfecting his engine like a poem"—compelled the world to awaken to a new era. The Age of Steam Power, of the Industrial Revolution. At the start, there were still many hardships to be overcome. Incompetent mechanics, inadequate tools, plans and drawings stolen and sold to rival companies, spies from Germany, France and Russia masquerading as workers and trying to appropriate the secret of the new agency "that threatened to revolutionize the world." One of their best engines was deliberately ruined by the engineer whom the representatives of a competitive concern had bribed with money and stupefied with drink. At another time a tempting offer was held out to Watt himself to leave his partner and to enter the imperial service of Russia. When Boulton heard of this offer, he wrote to Watt: "Your going to Russia staggers me . . . I wish to advise you for the best without regard to self; but I find I love myself so well that I should be very sorry to have you go."

Watt didn't go to Russia. He remained loyal to his partner, and together they surmounted their difficulties and rode to final suc-

cess. Orders for the Watt engine began to pour in, and Watt attended personally not only to the planning but to the installation of every machine. He had to be continually on the go. "I fancy," he wrote to his family from one of his trips to Cornwall, "that I must be cut in pieces and a portion sent to every tribe in Israel."

Incessant work on his steam engine—and, in his leisure hours, more work on all sorts of other inventions. A copying-press for manuscripts, a machine for drying clothes, a surveying-quadrant, a micrometer for the measuring of fine angles, a drawing machine, a sculpture reproducer, an instrument for the computation of distances between planets and stars, a method for determining the specific gravity of liquids, a reading lamp that "made the night almost as brilliant as the day"—and so on and on.

It was Watt, too, who discovered the composition of water. "Are we not authorized," he wrote (April 26, 1783), "to conclude that water is a compound of two gases—oxygen and hydrogen . . . ?"

And with all this, he found time to play. He joined the famous Lunar Society—an organization of writers and scientists devoted to an exchange or original ideas and mutual good will. The intimacy of this group, in the words of one of its members, "was never broken except by death." And the last surviving member of this "coterie of gifted minds" was James Watt.

VII

AND THUS he "gracefully glided into old age"—paying an occasional visit to Paris where his admirers, as he modestly expressed it, "kept me drunk from morning to night with Burgundy and undeserved praise"—accepting his honors with a quiet dignity and the death of a son with an equally quiet resignation. While not religious in the orthodox sense, he felt that in the summation of the whole the parts were somehow fitted into their appropriate grooves. "The mechanism of the universe seems to be running

without a hitch." The struggles of the individual—his ambitions, hopes, successes, failures, frustrations, tragedies and pains—were but the attendant commotions of the wheels as the world was being shaped into a perfect machine. Do your own part with as much efficiency and as little noise as possible. And when finally you are worn out, be content to be laid aside.

He gave over his interest in the Boulton and Watt partnership to his surviving son—an inferior inventor but cleverer business-man than his father. He bought an estate in Wales, planted trees, puttered in the garden, and "fooled around" with his inventions —he always referred to them modestly as "mere improvements" —to the very end.

And now, the last days of autumn. His fruits and his friends kept dropping off, one by one. "I run the risk of standing alone among strangers." But, he added, "perhaps it is a wise dispensation of Providence so to diminish our enjoyments in this world, that when our turn comes we may leave it without regret."

And it was without complaint that he answered the call of the Great Engineer. "I have finished my work. I am ready for the scrap-heap, to be remolded perhaps into a more satisfactory tool."

ROBERT FULTON

Important Dates in the Life of Robert Fulton

1765—Born, Pennsylvania.

1778—Invented paddle-wheels.

1782–85—Painted miniature portraits.

1786—Went to London.

1793—Interested in canal navigation.

1794—Patented mill for polishing marble.

1796—Interested in bridge building.

1797—Built submarine in Paris.

1801—Experimented with submarines at Brest.

1803—Launched a steamboat on the Seine.

1806—Returned to the United States.

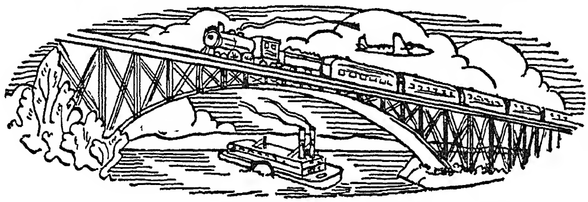
1807—Sailed steamboat Clermont *on the Hudson.*

1809—Took out patent on steam navigation.

1815—Died, New York.

Robert Fulton

1765–1815



One night in 1806, Robert Fulton was lecturing to a large audience in New York. He had just returned from Europe, where he had astounded the scientific world with his experiments on steamships, torpedoes, and submarines. The public was especially interested in that "most diabolical" of his inventions—an "underwater contraption of cylinders and explosives" which, regulated by clockwork, could be placed under an enemy ship and blow it up. He was explaining to his audience the mechanism of this invention. "The torpedo which you see before you is charged with a hundred and seventy pounds of powder. Attached to it, as you will note, is a bit of clockwork which regulates the timing of the explosion. Now let me remove the peg which plugs up the powder charge." An apprehensive stir in the auditorium. "Next," he continued, paying no attention to the uneasiness of his audience, "let me set the clock . . . There . . . And now, ladies and gentlemen, if I let this clock run ten minutes longer, we shall all be blown into kingdom come . . ." He tried to go on with his lecture, but there was no one left to listen to him. At the words

"blown into kingdom come," the entire audience, in a panic, had made for the nearest exits. "Robert Fulton and the Devil are in league to destroy the world!"

II

His FATHER was Scotch and his mother was Irish—a background which gave Robert the combined advantage of a tenacious will and a vivid imagination. He had need of both these characteristics from the start, for at the age of three he was left fatherless—a tough proposition for a youngster whose widowed mother had five children to feed and no income to fall back upon. Poor food, a frail body, and an everlasting itch to be doing something with his fingers. He didn't care for the three Rs, which his mother taught him, nor for his lessons in school—which he entered at the age of eight. "This child," said his teacher, "will not even have an ordinary education." No, his education was most extraordinary—and through his own choosing. He never knew how to spell correctly; but he knew how to make a lead pencil superior to the one that his teacher gave him. "Why don't you study your books?" his teacher asked him.

"I dunno, sir. Guess there are so many thoughts in my head, I can't crowd no thoughts into it out of my books."

"Can't crowd *any* thoughts into it! And no more of your impertinence, young man!"

"Yes, sir. Can't crowd *any* thoughts into it. And I won't be impertinent no more."

Incorrigible child. Just *wouldn't* learn his grammar. But he learned how to make all sorts of little gadgets in the blacksmith shops and the tinsmith shops of Lancaster (Pennsylvania). And he drew original designs for ornamenting the rifles that were manufactured in the village arsenal. "A pretty good draughtsman and a very good mechanic."

And a youngster with an inventive mind. One Fourth of July

he decided to have a new kind of celebration all by himself. Bringing to the general store a number of candles which he had saved up for the occasion, he exchanged them for a bag of gunpowder and several sheets of pasteboard. "Please don't roll up these sheets, Mr. Howard," he said to the storekeeper.

"All right, if you say so," replied the storekeeper. "But tell me what you're going to do with them."

"Wait till tonight, and you'll see."

That night the villagers were startled to see Robert's "newfangled shooting candles" flashing through the air. The thirteen-year-old inventor had become the celebrity of the town.

Always inventing things. Always drawing pictures. And oftentimes getting into trouble because of his too fertile imagination. On one occasion he precipitated a fight between the townspeople and the Hessian soldiers who were quartered in the neighborhood. The town authorities, in order to avoid trouble between the civilians and the soldiers, had stretched a rope at a designated place with instructions that neither the townspeople nor the Hessians were to cross that rope. Whereupon Robert drew a picture of the townspeople invading the Hessian side of the rope and putting the enemy to the sword. This provocative picture, displayed in the public square, served as an instigation to both sides. A serious riot broke out, and it was only with difficulty that the cooler heads among the two factions were able to prevent bloodshed.

Stirring times, and stirring thoughts. Robert couldn't make up his mind as to his future career. Should he devote himself to mechanics or to painting? Or, perhaps, to fighting? General Washington needed plenty of fighting men. But Robert was neither strong enough nor old enough for the rigors of a military life. "You are meant for the peaceful pursuits, my boy," said his mother. She sent him to Philadelphia, where for three years he knocked about as a jeweler's apprentice, an architect's assistant, and an occasional painter of miniature portraits.

One of the men whose portraits he painted was Benjamin Franklin. The elderly statesman encouraged him in his work and secured him commissions from several personages of "manners and means." Robert was on the way to making for himself a tidy sum when his career was cut short for the time being. An inflammation of the lungs, accompanied by the spitting of blood, sent him to the warm springs of Virginia.

Recovery, and a return trip to Philadelphia. He had planned, during his convalescence, to try his fortune in England. He wanted to ask Franklin's advice about this plan. "You are right, young man. England is the place for an artist. America is too young, too eager to achieve. We have no time here for the leisurely appreciation of art."

He gave Fulton a letter of introduction to Benjamin West, the American painter who had made his mark in England. Fulton thanked his benefactor, invested the greater part of his savings in a farm for his mother, and set sail for England with a capital of forty guineas (about two hundred dollars) in his purse. "How foolish of him," said a friend, "to have decided upon the two most unprofitable careers in the world."

"Yes," nodded another. "Painting and inventing—a wild-goose chase with an empty gun in either hand."

III

London, and a devoted intimacy with Benjamin West. Under the elder artist's inspiration, Fulton made rapid progress as a portrait painter. On two occasions his pictures were exhibited at the Royal Academy. His American friends had been wrong in their predictions. His artistic career was bringing him not only profit but prestige. "His portraits," wrote an eminent critic (Charles Henry Hart), "are well drawn, good in design, delicately colored, and well executed technically."

Yet Fulton was not content. If he stuck to his art, he would

remain a competent painter all his life. But that was not enough. What he wanted was not competency, but mastery. And so he gave up the promise of his artistic career for the uncertainty of his engineering adventures. "Now at last," said everybody, "young Fulton has gone definitely mad."

Definitely and stubbornly mad to turn his creative ability into constructive good. Fulton possessed that rare combination of genius—Leonardo da Vinci was another man who possessed it—he was at once scientific in his art and artistic in his science. He reduced every object to a specific design and developed every design into a provocative picture. It was therefore an easy transition for him to transform his canvases into blueprints—to advance from the copying of existing shapes to the shaping of new existences. In rapid succession he invented a machine for spinning flax, an appliance for twisting ropes, and a mill for polishing marble. First the thought, then the plan, and finally the finished product. "He never made a model of an invention until he had completed a drawing which showed every part projected on the proper scale."

All these inventions, however, were but a preparation for his life's work—the lessening of the distance, both mental and material, between man and man. It was his ambition from now on to facilitate travel, to stimulate commerce, and to discourage dissension and war. For his interests were not only artistic and scientific; they were also political. "The establishment of Republicks throughout Europe . . . and the study of the Art of Peace should be the aim of everybody." Certainly it was the aim of his own inventive labors. He tried to develop a system of canals in England and on the European continent, so that the Old World might be more closely united into a confederation of free and friendly states. He spent a number of years on the invention of the submarine and the torpedo—two weapons whose destructiveness, he hoped, would bring about "the end of naval oppression and the establishment of peace through an agreement of nations."

And he worked incessantly on his new "eagle of the sea"—a steam-propelled ship whose speed would "narrow the sea into a strait and turn America and Europe into next-door neighbors."

The dreams of a deranged mind, was the almost universal verdict when he spoke of his plans. One day he was invited to dinner at a friend's house. Next to him at the table sat Prince Talleyrand. The two men conversed about Fulton's inventions, especially the steamboat. After the dinner the host asked Talleyrand for his opinion of Robert Fulton. "A charming man and brilliant conversationalist. But"—and Talleyrand shook his head sadly—"I'm afraid the poor fellow's cracked."

This fear that Fulton was cracked compelled many an influential person to fight shy of him. Owing to the high cost of his materials, he was always in need of funds. And almost always he was refused when he requested a loan. "My money," said one of the wags who denied his request, "would only float away on the sea or go up in flames." Once, when he was working on the steamboat, he was in absolute need of a thousand dollars. He went to a wealthy friend and asked him to advance this sum as an investment. "You don't expect me to throw away a thousand dollars," said his friend. "But I'll tell you what I'll do. I'll give you a hundred dollars if you can get me the names of nine other people who will advance a hundred dollars each." With great difficulty Fulton succeeded in raising the nine hundred dollars. But he couldn't get the money from the friend who had offered the original hundred. For he couldn't give him the names of the other nine contributors. Every one of them had refused to subscribe publicly to "so crazy an adventure."

IV

In the course of his travels to interest people in his inventions, Fulton had an interesting episode with a French noblewoman—the wife of the Vicomte de Gontaut. It was during the crossing of the English Channel that he met her. We have the story in her

own words: "Our family having been proscribed at the time of the [French] Revolution, I was returning to Paris in connection with the management of our property. In order to avoid detection, I had assumed the name of Madame François, 'a dealer in laces going to Paris on business.' One day, as I was sitting on the deck, an Englishman of striking appearance and charming demeanor came and spoke to me in halting French. He was delighted when he learned that I could speak English. 'Madame,' he said to me, 'you could do me a great favor if you would act as my interpreter.' I promised him I would. He then told me that he was an inventor of amazing machines—boats that could sail under the water and blow up ships on the surface, vessels driven by steam power that could outspeed any sail-driven craft, and several other devices that sounded like tales out of the *Arabian Nights*. I listened to his talk with genuine interest, and I agreed to introduce him to various important Parisians who might help him to further his plans."

On her arrival in Paris, however, she was arrested as a noblewoman in disguise. Fulton visited her in the detention room. He had in his possession, he told her, a letter recommending him to Monsieur Barthélemy, one of the Directors of the French Republic. "With this letter, madame, I can set you free—provided you will do me the honor to become my wife."

"But, monsieur, I am still married to my husband."

"What a pity, Madame François, what a pity! I would make you rich. My inventions are going to set the world agog. Just say the word. Divorce Monsieur François and come to me. I will marry you, and that will be the end of your troubles."

But "Madame François" shook her head. "I didn't dare at the time to tell him that I was traveling under a fictitious name, and that in reality I was the wife of a French nobleman."

A few weeks later she managed to secure her release through the influence of one of her friends—Herr Schemelpeninck—the German consul to Paris. She had now, for safety's sake, assumed

her maiden name. One day as she was walking in the street with her brother-in-law, her "English inventor" rushed up and seized both her hands. "Ah, Madame François, I am so happy to see you!"

"Pardon, monsieur," said her brother-in-law, "but zis is not Madame François. You have ze honor to address Mademoiselle de Montault."

Fulton shrugged his shoulders and walked away. He couldn't make out the mystery. Was it the same woman or a twin sister?

Several months elapsed. Fulton had returned to London. One night at the opera he saw his "mysterious lady" sitting in the box of a friend of his. He made his way to her side. "What an unexpected pleasure to meet you here, Mademoiselle de Montault!"

"Monsieur is mistaken," said her escort. "The lady you are addressing is the Vicomtesse de Gontaut."

"What, triplets?" muttered Fulton under his breath. Aloud, however, he said with a smile: "Madame, allow me to congratulate your husband on being married to the three most beautiful women in France."

V

It was through Madame de Gontaut that Fulton was able to interest the French ministers in his submarine and steamboat experiments. In December 1797 he made his first attempt—on the Seine—to blow up a ship with a submarine. The attempt was a failure, both Fulton and his assistant escaping narrowly with their lives. Undeterred by the setback, he went ahead and built another submarine. This "undersea battleship" aroused the interest of Napoleon, who was at the time (1801) planning an invasion of England. "The sea which separates you from your enemy," Fulton wrote to Napoleon, "gives him an immense advantage over you. Aided . . . by the winds and the tempests, he defies you from his inaccessible island. I have it in my power to

cause this obstacle which protects him to disappear. In spite of all his fleets, and in any weather, I can transport your armies to his territory (and destroy his ships) in a few hours . . . I am prepared to submit my plans."

Napoleon invited him to submit the plans and to demonstrate their effectiveness. In the summer of 1801, Fulton succeeded in "blowing a boat into atoms." The submarine was a proved success. Fulton was elated. "At long last we have an instrument that will do away with the erroneous system of exclusive commerce and distant possessions . . . the obstacles which hinder nations from arriving at a lasting peace."

But Napoleon and his ministers were not so sanguine about the usefulness of the submarine. "It would be impossible," said the Minister of Marine, "to give commissions to men using such an instrument in war, as these men would surely be hanged if captured." Fulton's invention was turned down.

Disappointed with his failure to interest the world in the submarine, Fulton now turned his entire effort to his next idea—the steamship. In this idea—the possibility of steam navigation—he was not alone. Both in America and in Europe there were a number of scientists preoccupied with experiments in this field. One of these scientists, Robert R. Livingston, was in 1801 appointed minister to France. The two Roberts—Fulton and Livingston—were drawn together through their similarity in temperament and taste. Fulton had the ideas, and Livingston had the funds. They formed a partnership which turned out to their mutual advantage and to the benefit of the entire world.

At the outset, however, they had anything but smooth sailing. In the early spring of 1803 they were ready with their model steamboat. It was anchored on the Seine, waiting for its initial experiment. One morning Fulton was roused from his bed. His boat, he was told, had sunk in the night. He rushed to the spot. Sure enough, the boat was split in two. The iron machinery in the center had proved too heavy for the wooden structure.

Plunging into the icy water and working incessantly for twenty-four hours, Fulton succeeded in raising the boat. The machinery was intact, but the framework was a wreck. So too, for a time, was his health. But Fulton went right on rebuilding the boat, and in the summer of that same year was ready for the test.

On August 10, 1803, the following account of the historic event appeared in the *Journal des Débats:*

". . . During the past two or three months there has been seen at the end of the quay Chaillot (on the Seine) a boat of curious appearance, equipped with two large wheels, mounted on an axle like a chariot, while behind these wheels was a kind of large stove with a pipe, as if there was some kind of a small fire engine intended to operate the wheels of the boat . . .

"The day before yesterday, at six in the evening, the inventor . . . put his boat in motion . . . and for an hour and a half he produced the curious spectacle of a boat moved by wheels, like a chariot, these wheels being provided with paddles or flat plates, and being moved by a fire engine . . .

"The boat ascended and descended the stream four times from Les Bons-Hommes as far as the pump of Chaillot; it was maneuvered with facility, turning to the right and left, came to anchor, started again, and passed by the swimming school . . .

"This mechanism, applied to our rivers—the Seine, the Loire, and the Rhone—will have most advantageous consequences upon our internal navigation. The tows and barges which now require four months to come from Nantes to Paris would arrive promptly in ten to fifteen days . . ."

Again Fulton had offered a valuable gift to the French Government, and again the offer was turned down. Napoleon and his ministers gave due consideration to the "experiment on the Seine," and decided that the steamship, like the submarine, was a "useless toy."

Fulton was now thoroughly disgusted with France—not only for personal but also for political reasons. When he had first

visited that country the Reign of Terror had given way to the promise of freedom. His democratic spirit had thrilled to the hope of a new day for Europe when despotism would be a thing of the past. It was a great shock to him, therefore, to see the accession of Napoleon to the office of First Consul. "The French Revolution is dead. The French people have merely exchanged one despot for another." Fulton longed to breathe once more the air of a free country. He took passage to America.

And to final glory. Together with Livingston, who had returned from his diplomatic post in the Old World, he built a steamship —the *Clermont*—in the East River, and one day quietly sailed around the tip of New York and over to the New Jersey shore. It was a most successful trip. Fulton and Livingston were now ready for their first public test.

The public, however, had nothing but jeers for "Fulton's Folly" —the nickname given to the boat by one of the New York wit-snappers. "The thing," wrote a journalist who had gone down to examine the boat, "is an ungainly craft looking precisely like a backwoods' sawmill mounted on a scow and set on fire."

Yet on the day of the trial—August 17, 1807—a large number of spectators gathered on the banks of the Hudson River. "While we were putting off from the wharf," wrote Fulton in a letter to a friend, "I heard a number of sarcastic remarks." Excitement, incredulity, ridicule, scorn—and then silence, followed by a shout of spontaneous applause. "Holy Jupiter, the thing does work!" yelled one of the spectators hysterically as the *Clermont* wheeled across the river, made a clean-cut turn upstream, overtook sloop after sloop and "parted with them as if they had been at anchor."

Three weeks after the trial—from the seventh to the eleventh of September—the *Clermont* sailed up the Hudson to Albany and back. The trip was a continuous triumph. Throngs of people on the banks and in boats looked on "with awe almost amounting to terror," as the water chariot rolled over the Hudson, her funnel spouting forth a pillar of cloud by day, a pillar of fire by night. A

scene reminiscent of the Old Testament—the finger of God pointing the way to a new Canaan, the Promised Land of speedier communication and better understanding between man and man. "The power of propelling boats by steam," as Fulton wrote to one of his sponsors, "is now fully proved."

VI

THE REST of Fulton's life may be summed up in a few words. A late marriage and an early death. He was forty-two when he married—there were four children resulting from the union—and only forty-nine when he died. As a mark of respect, the only one of its kind ever shown to a private citizen, the New York Legislature passed a resolution that both houses should wear mourning for six weeks.

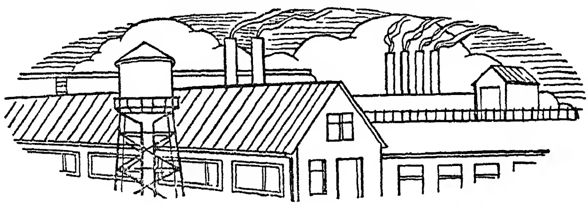
ELI WHITNEY

Important Dates in the Life of Eli Whitney

1765—*Born, Westboro, Mass.*
1792—*Graduated from Yale.*
1793—*Invented cotton gin.*
1794—*Patented invention.*
1798—*Commenced manufacture of firearms at East Rock, near New Haven.*
1807—*Received legal decision upholding validity of his patent.*
1812—*Applied for renewal of patent.*
1825—*Died, New Haven, Conn.*

Eli Whitney

1765–1825



EVERYBODY has heard of Eli Whitney as the inventor of the cotton engine, a mechanism which revolutionized the industry of the South. But very few have heard of him as the inventor of a still greater mechanism—a discovery which revolutionized the industry of the world. The first of his inventions brought him nothing but poverty and distress; the second repaid him with dignities and distinctions and wealth. Yet today he is remembered primarily as the father of the simple cotton gin and almost forgotten as the founder of the complicated method of mass production—that is, the large scale manufacture of machine-made instead of hand-made tools.

In this story we shall trace the development of the genius that started with the loosening of the cotton from the seed, and ended with the forging of machinery to produce machines.

II

ELI WHITNEY came of a line of Yankees who spent their summers in farming and their winters in tinkering and whittling. For the

pre-Revolutionary American had to produce not only his own food, but—to a great extent—his own clothing and utensils and tools. And thus he was able to develop a "mechanical mind" and a pair of clever hands. The Whitneys of Westboro, Massachusetts, were no exception to this rule. Eli's father, Eli Whitney Senior, had a workshop as well as a farm. And the child was to be found more frequently in the shop than in the fields. Even in the spring and the summer months, when every member of the household was needed for the heavy outdoor work. "That boy don't fit somehow. Don't seem to realize there's a proper time for everything. Ain't exactly stubborn, but just don't fit."

Never cut out for a farmer, young Eli. But what a mechanic! Only twelve, and already he had whittled out a violin, all by himself. And one day, when his father's watch got out of order, he took it apart, fixed it, put all the wheels together again—and there it was, as good as ever.

And then, still in his early 'teens, he became the best "repairman" in the village. Fiddles, watches, chairs, lanterns, spinning-wheels, plows, tables, beds, hatpins, knives, needles, tongs—"there's nothing too big or too tiny for those clever fingers of his."

During the Revolutionary War "the lad with the magic hands"—he was too young for the fighting—became established in his own business. He forged nails for the army; and he employed, as his assistants, two full-grown men.

And then, upon his father's advice, he decided to give up his "tinkering" and to prepare himself for college. "When the war is over," his father declared, "our country will need lawyers as well as mechanics."

And so he turned from the lathe to Latin—a much harder instrument for his unclassical mind. Incessant study—"whatever he does, he puts his whole heart and soul into it"—teaching in his spare time, and a protracted siege of fever which almost ended his life. At last he was sufficiently recovered to take his examinations for Yale.

He passed. "Rather old for a Freshman"—almost twenty-four now—"but seems a likely prospect for the law."

His friends at Westboro, however, shook their heads when he entered Yale. "Another good mechanic spoiled by a college education."

And throughout his college career it was a struggle between the mechanic and the lawyer. His fingers kept tinkering with the college instruments even when he had to prepare for his examinations. Didn't seem to realize, even now, that there was a proper time for everything.

Yet even his college professors were compelled to admit that the time he spent on his "tinkering" was not all wasted. During the Christmas week of 1789 Doctor Ezra Stiles, the president of Yale, received a number of "philosophical" instruments from England. One of the instruments—an *orrery,* or "clockwork device for teaching the movements of the planets"—had been broken in transit. Doctor Stiles was about to return it to England; for "in all America there is not a single artist competent to mend it."

Eli Whitney asked for permission to take the instrument apart. "As a boy, Sir, I took my father's watch apart."

"But this instrument, young man, is far more intricate than a watch."

"I'll see what I can do, Sir, with your permission."

Reluctantly, and against the advice of some of the professors, the president turned the instrument over to the young student. "I'm sure he'll bungle it," said his tutor, "just as he always bungles his Latin declensions and conjugations."

"But I'm not so sure," rejoined Doctor Stiles. "I've seen his fingers at work."

It took Whitney several weeks, and an original set of tools that he designed at a mechanic's shop in New Haven, before he could repair the astronomical instrument. But finally he turned over a perfect job to President Stiles. "The college," reported Doctor

Stiles to the overseers, "has been saved a hundred dollars by one of its students."

A fair-to-middling scholar, but a mechanical genius. To Whitney he said: "I'm not so confident of your skill as an advocate, but I'm quite convinced of your talent as an artist."

An artist in the creation of mechanical tools.

III

After his graduation from Yale (in 1792), he received an offer to teach at a plantation school in Athens, Georgia. The salary was to be a hundred guineas—about $510—a year; and his tutorial duties would leave him plenty of time for his legal studies. And for his mechanical experiments. He accepted the offer.

En route to Georgia, he met the widow of General Nathanael Greene, of Revolutionary fame. Mrs. Greene induced him to pay a visit to her Savannah plantation. There was a smallpox epidemic raging in the neighborhood when he arrived. Whitney helped with the inoculation of the slaves. A likable but lazy lot. No wonder the South was so impoverished. It took a slave an entire day—and then only if the foreman could keep him awake—to pick the seeds from a single pound of cotton.

One evening, as Mrs. Greene was entertaining a number of planters, the conversation turned upon this subject. Whitney was an interested listener. A new subject, new horizons. He learned, among other things, that it was only the inland—or the so-called "green-seed"—type of cotton which was so hard to disengage from the seeds. There was another type of cotton—the "sea-island" kind—which grew only on the seashore or on land that was entirely surrounded by water. This cotton had slippery black seeds which could easily be made to "pop out" of the plants by means of rollers.

But this sea-island cotton, as Whitney learned, was useful only for the better kind of fabrics—the "clothing for the aristocrats."

The rougher fabrics—the fustians and the work-clothes for the masses—could be spun only out of the green-seed cotton. "There's a great market for this green-seed stuff," observed one of the guests. "And there's a fortune waiting for the man who could invent a gin to remove the seeds without crushing them into the lint."

"Gentlemen," remarked Mrs. Greene, who had also been listening to the conversation, "I believe we have right here the man who can do it." She pointed to Whitney, in whose mechanical genius she had come to have the utmost faith. For he had contrived all sorts of ingenious gadgets for her during his short stay at the plantation.

But Whitney only blushed at her remark. "Thanks for the gracious compliment," he stammered. "But I'm afraid it's out of the question. Why, I don't even know the meaning of the word *gin.*"

"Gin," explained another of the guests, "is merely our lazy Southerners' name for *engine.*"

And there, for the time being, the subject was dropped. The planters, like Whitney himself, had taken Mrs. Greene's remark as a mere compliment. And so they carried the conversation into other channels and forgot all about the young "intruder" from the North.

But Whitney, when he went up to his room that night, didn't forget the conversation. What if he *could* contrive a mechanism that would increase the output of the green-seed cotton? It might mean any number of things—a revival of planting in the South, of textile manufacturing in the North, a transformation in the entire field of slave labor, and Heaven knows what other industrial readjustments this transformation might lead to. But most important of all, it might mean fame and fortune for himself.

The idea intrigued Whitney—especially in view of the bad news he had just received from Athens. The proffered salary for his new teaching job had been reduced from a hundred to fifty

guineas a year. Hardly enough to live on; no savings out of *that* for his legal studies. Besides, his prospective employers were apparently unreliable. They had no business to make him come all this way on a false promise.

Perhaps, after all, it was the finger of God pointing out the direction of his life's work. "Maybe I'm not meant to be a teacher or a lawyer." A long, sleepless night of self-questioning, and in the morning he had made up his mind. "Mrs. Greene, I've decided to try my hand at that cotton gin."

IV

It took him but a short time to complete the first model. And its simplicity amazed the planters. Why hadn't they thought of it themselves? A rotating spiked cylinder that pulled the cotton through a comb-like structure of narrow slots. The slots were just big enough to allow the passage of the fleecy cotton, but they were too small to allow the passage of the stubborn seeds. And so the seeds fell back into a receptacle constructed for the purpose, while the cotton was combed out by a revolving brush into fibers all ready to be shipped to the mill.

"Why, even a child can understand it."

"Yes, and a child could have made it."

And this remained the attitude of the planters toward Whitney's invention to the very end. He patented his model, but not until after it had been stolen from Mrs. Greene's attic in which he had made it. And almost overnight, the entire South had blossomed into cotton fields and gins. In vain Whitney and Phineas Miller, the partner he had secured for the manufacture of the engine, spent their time and money in appeal after appeal to the courts. The planters, jealous of the "Yankee trouble-maker," insisted upon their "divine right" to build their own gins "since God has given us the privilege to grow our own cotton." And—so chaotic were the patent regulations of the period—he came out

of the long and losing fight against the planters not only penniless but several thousands of dollars in debt.

And in the meantime the planters, thanks to Whitney's invention for which they had repaid him with stones, pocketed many millions of dollars for themselves. And more than that, they put additional millions of dollars into the pockets of the textile manufacturers of New England. Owing to the rapidity with which the gin could extract the seed from the fiber, the annual production of cotton in the United States increased from 140,000 pounds in 1791 to 35,000,000 pounds in 1800.

And Eli Whitney, to whom all this prosperity was due, continued to struggle in poverty and obscurity and disgust. "My beneficiaries are rolling in wealth, whilst I can't afford a suit of cotton combed out upon one of my own gins."

At last the government of North Carolina and of South Carolina paid him $50,000 for his patent. But this long-overdue reparation was just about enough to liquidate his debts.

And Whitney remained as poor as ever. And as determined as ever to continue his struggle for a happier life.

V

But now his struggle took a different turn. No more exhaustive battles for his legal rights. He remembered the ironical observation of Benjamin Franklin. "All my money," said Franklin, "has been eaten up in two legal battles—one-fourth in the first battle which I lost, and the other three-fourths in the second battle which I won."

From now on, Eli Whitney would be no longer an inventor fighting for his patents but a manufacturer working for his profits.

And, as he examined the manufacturing possibilities of America at the turn of the century, he decided upon muskets as one of the likeliest ventures. For at the time there was considerable talk

about the military menace of England, of France, of every other nation strong enough to put its jealousy of the new republic to the test of arms.

He would therefore go into the manufacturing of arms—on a tremendous scale. Machine production of muskets to replace the hand-produced botchery of the past. An idea never tried before. The invention of machines to *make* machines. An inventor turned manufacturer. Or, rather, a manufacturer guided by an inventive mind.

And now, once again, an uphill fight. But this time he was destined to reach the top.

He started his new fight with the help of several Congressmen whose friendship he had won during his cotton-gin struggle. These political friends introduced him to a committee of military experts in Washington. A rather skeptical group. "The old muskets are good enough for us. They helped us win the Revolutionary War, didn't they?"

"But, gentlemen, new times require new methods—whether in peace or in war."

The experts remained still unconvinced. "You'll have to show us a pretty good specimen, Mr. Whitney, before we can consider your musket."

"Very well, gentlemen, I am ready to show it to you." He motioned to an assistant, who brought a box into the committee room. He opened the box and placed upon the table, in separate piles, the pieces of ten dismantled muskets—ten locks, ten triggers, ten barrels, ten stocks, ten frizzens, and so on to the end. "And now, gentlemen, will one of you please pick up any complete set of parts from these various piles and put them together. You will find that the set will make a perfectly-fitted musket."

"Do you mean," asked a committee member, "that *any* set of parts, taken at *random,* can be fitted together into a finished *product?*"

"Yes, Sir, this is precisely what I mean."

"But Mr. Whitney, this is impossible! No part of any one musket has ever been made to fit into any other musket. Don't forget the element of inaccuracy in the human hand and the human eye. No two barrels, no two triggers, no two lock-plates have ever been exactly alike."

"Quite right, Sir. But mine *are* exactly alike. For they are not hand-made. They have been measured and manufactured by the scientific accuracy of the selfsame machine. Hence these parts are not only *alike* but *interchangeable.*"

And sure enough. When the piles were all unscrambled and interchanged and then fitted and screwed together part to part, there were ten complete muskets ranged on the table side by side. "And better muskets," declared Noble Orr, the government inspector of small arms, "I have never seen."

The members of the committee were now satisfied as to the *quality* of Whitney's product. But they were still skeptical about his ability to produce it in sufficient *quantity*. An advance of thirty thousand dollars for the manufacture of ten thousand muskets resulted, at the end of two and a half years, in a "clutter of strange engines and only five hundred finished pieces."

But Whitney had an explanation for that. He had consumed the greater part of the two and a half years in the invention of the machines for the making of these arms. A separate machine for every separate item. A stupendous job. But now the machinery was all completed and he was ready—he declared—for production on as large a scale, and within as brief a period, as the government might demand.

And he was true to his word. Ten thousand muskets, and then twenty thousand more. And all of them delivered on the promised date. A new invention—the most stupendous invention of them all, perhaps—the wholesale manufacture of engines for war.

And of instruments for peace. For the idea of large-scale production could be applied to the making of engines that would *enrich life* instead of putting *an end to life*. Tools for the factory

and the farm, timepieces for the office and the home. Machinery to lessen the drudgery of man and to multiply his comforts. And —who knows?—engines for the quicker transportation of goods and the wider dissemination of ideas. Mechanical devices for the bringing of mankind to a closer communion of interests and hearts. Such were some of the thoughts that occupied him in his spare moments.

For Whitney was a poet as well as an inventor. He had written verses in his college days; and even now he caught himself frequently adrift on the current of his fanciful dreams.

He spoke about some of his dreams to his more understanding friends. Especially to Thomas Jefferson, whom he had met during his negotiations with the government for the manufacture of his muskets. Two men of peace engaged in the preparation for war. "Muskets are necessary," Jefferson had once said to him, "for the protection of our liberty against the aggressors of the world—the men and the nations that feel power and forget right. But God grant the day when such aggressiveness shall be a thing of the past."

Jefferson was fingering one of Whitney's muskets as he spoke these words. "And when that day comes, Mr. Whitney, other inventors and other statesmen will be able to make better use of their energies than you and I."

VI

Whitney devoted the rest of his life to the manufacture of arms. "For our country's defense, but never for aggression." He had himself experienced too much suffering from the commercial aggressors of the South. They had stolen his invention, and they had fought and won an unjust fight against him in the courts.

And now he was through with his fighting. He took out no patent for the invention of his gun-making machinery. Let them copy his ideas if they wished. He would attend to his own business

Robert Fulton

Eli Whitney

making better machines—and let those who had a taste for it "depend upon the subtleties of the law to defend the thieves."

A strange world, he mused as his musket factory kept piling up more and more profits for him in his declining years. His *patented* invention had brought him to the brink of disaster. His *unpatented* invention had brought him to the end of the rainbow with its pot of gold. He was now able, at long last, to get married and to support a family. But almost too late for his own happiness. He was too old, and too tired, to get the full enjoyment of the blessings that had been his due in his earlier days. Long periods of illness now—"sleepless nights of pain on a gilded bed."

A strange world, with its strange rewards. Health in poverty, illness in wealth—and the imminence of death when he had just entered upon the threshold of a happier life. He was only sixty when he knew that the end was near. "But I will not complain. Time to make room for better ideas, worthier ambitions, and nobler men."

HUMPHRY DAVY

Important Dates in the Life of Humphry Davy

1778—Born, Cornwall, England.

1794—Apprenticed to a surgeon-druggist.

1798—Appointed superintendent of Dr. Beddoes' Pneumatic Institute.

1799—Investigated nitrous oxide.

1801—Assumed post as assistant lecturer and director of the laboratory of the Royal Institution.

1807—Decomposed the fixed alkalis, isolating potassium and sodium.

1812—Knighted by the Prince Regent.

1813—Published Elements of Agricultural Chemistry.

1815—Invented a safety lamp for miners.

1818—Became a baronet.

1820–26—Served as president of the Royal Society.

1829—Died, Geneva, Switzerland.

Humphry Davy

1778–1829

SIR HUMPHRY DAVY was a chemist who devised a safety lamp by the light of which miners were able to work in the pits secure in the knowledge that the danger of explosions had been greatly diminished. The invention of the safety lamp made possible the expansion of the coal industry which, in turn, spurred the Industrial Revolution.

But Davy was more than an inventor. He was an Aristotle among nineteenth-century scientists. His comprehensive mind fertilized the fields of agriculture, economics, politics, natural philosophy. Fascinated by belles-lettres as well as by test tubes, he associated with the outstanding poets and writers of Europe. The flashes of his wit illuminated their thinking. The ineffable charm of his manner drew the cream of society to his feet. Knowledge assumed an added enchantment for being expressed through him. World famous at twenty-two, as graceful as a Greek Apollo, as haughty as a biblical prince, Davy lived brilliantly and died prematurely. At his death, science added one more glowing star to its horizon.

Davy's father was a wood carver in Cornwall, a shiftless ne'er-

do-well. His mother, however, was energetic. She organized her children and directed their talents. She remained their lodestar to her final hour.

Humphry was a sensitive lad. The rocky coast of Cornwall, his birthplace, had inspired the minds of poets with the legend of *Tristram*. Davy's imagination also rose to the possibilities of this countryside. Coleridge once remarked that if Davy had not been the foremost chemist of his age, he could have become one of the outstanding poets. As long as he lived he expressed his innermost thoughts—too deep for tears—in the language of verse.

Nothing in Davy's formal schooling prepared him for the intellectual life he was destined to lead. He entered the wilderness of learning without a guide. He found his way alone. At first he taught himself by reading books at random. Then eventually he systematized his reading, marking out for himself a course of study "almost unparalleled in the annals of biography." While other lads were still teething, intellectually, he devoted himself to the philosophies of Kant, Berkeley, Hume and Locke. At eighteen he passed from metaphysical to physical knowledge. He "attacked" mathematics in earnest. A year later he introduced himself to chemistry.

The druggist's shop in which he served his apprenticeship was ideal for his early experiments. He made liberal use of the weights, acids, liquid measures and crucibles. His experiments terrified his relatives. "That boy will blow us all into the air!" they complained. Frequently he employed his sister to assist him. Yet, although she ruined her dresses with his chemicals, he remained frigid to her tears.

Davy's interest in science was further stimulated by various friends. Among them was Gregory Watt, the son of James Watt, the celebrated inventor of the steam engine. Afflicted with tuberculosis, Gregory came to Cornwall for a rest, and he boarded in the house of Davy's mother. He had studied science at Glasgow University, and he took long walks by the ocean with the young chemist, exchanging the currency of ideas.

A remarkable opportunity to widen the field of his investigations was presented to Davy while he was still in his teens. A certain Doctor Thomas Beddoes, convinced that the respiration of certain gases could have a definite therapeutic value in the war against disease, established an institution for medical research supported by private subscription. Upon the recommendation of a mutual friend, he offered young Davy the opportunity to direct his laboratory. Davy joined Dr. Beddoes and became nationally famous.

II

DAVY'S BRILLIANT CAREER as a chemist was launched at Dr. Beddoes' Pneumatic Institute. He broadened in every way, socially as well as occupationally. Possessing a genius for making friends, he was in close association with some of the leading men and women of England before he was twenty: Coleridge and Southey, the poets; Maria Edgeworth, the novelist; Josiah Wedgwood of pottery fame, to mention a few.

All these were vigorous personalities. Hardly less was his colleague, Dr. Beddoes, who was certainly as eccentric a physician as lived in England. The institute was a scene of bizarre investigations. One of Beddoes' theories was that the inhalation of cow's breath was beneficial to his patients. Accordingly, the doctor brought cows into the bedrooms of the sick. They filled the hospital with a most disagreeable odor.

Davy matched Dr. Beddoes' standards of novelty with his own unorthodox experiments. Turning his attention to nitrous oxide, he shut himself in an air-tight room into which quantities of the gas were periodically introduced. He breathed it three times daily for weeks, and then he published the results. "A thrilling feeling extended from the chest to the extremities. . . . By degrees, as the pleasurable sensations increased, I lost all connection with external things. . . . I existed in a world of newly

connected and newly modified ideas. I theorized, I imagined that I made discoveries. When I was awakened from this semi-delirious trance by Dr. Kinglake who took the bag from my mouth . . . I exclaimed . . . 'Nothing exists but thoughts!' "

Always the poet, Davy experimented further with nitrous oxide to determine whether it would stimulate his muse. He inhaled it in the bright moonlight and wrote stanzas under its intoxication.

As might be expected, Coleridge, Southey, Maria Edgeworth and other friends were vitally interested in methods of improving their "divine inspiration." Following Davy's instructions, they breathed the gas "which inebriates in the most delightful manner" and dutifully recorded their sensations.

As a matter of fact, nitrous oxide was transformed into a "seven-days" wonder in England. Inasmuch as in the early stages of stimulation it caused the "victim" to laugh uproariously, it was dubbed "laughing gas." In his notes Davy wrote of its value as an anesthetic. Indeed he employed it to relieve the pain of a wisdom tooth. Yet physicians disregarded his hint for almost half a century. The search for an anesthetic would have been crowned much earlier with success if medicine had not overlooked Davy's observations.

Upon the publication of his experiments with nitrous oxide, Davy received congratulatory letters from everywhere. The venerable Joseph Priestly, the discoverer of oxygen, wrote to the young buck of twenty: "Sir . . . it gives me peculiar satisfaction that, as I am far advanced in life and cannot expect to do much more, I . . . have so able a fellow laborer . . . in the great fields of experimental philosophy."

No wonder Davy's head was turned! "I am sorry to be so much of an egotist," he declared to a friend with a swagger, "yet I cannot speak of the Pneumatic Institute and its success without speaking of myself."

His associates did nothing to lessen Davy's conceit. When asked how the young chemist compared with the cleverest men in

England, one of his followers replied: "Why Davy can eat them all!"

As a result of his research, Davy left the laboratory of the Pneumatic Institute for a much better position. He received an engagement to lecture and teach in London, the "hub of society." And he really "came into his own."

III

In 1799, a group of Englishmen led by Benjamin Thompson, a former American loyalist, founded the Royal Institution. This was an establishment designed to improve the living conditions of the poor. Through the Institution, it was hoped, inventions would be introduced to promote economies for the underprivileged. As an evolution from its philanthropic origins, the Institution became chiefly devoted to the cause of science.

Davy, well-known for his experiments at the Pneumatic Institute, was offered a position as director of the laboratory and an assistant professorship of chemistry with the promise that he would be made a full professor within a couple of years. The young chemist yielded to these blandishments. He entered the Royal Institution as an assistant lecturer, and quickly stamped it with the imprint of his personality.

When first he arrived at the Royal Institution, it appeared financially to be headed "toward the rocks." But Davy changed all that. He gave a series of lectures on chemistry which brought fashionable London to his feet. Hitherto, science had been the preserve of specialists. He made it the glamor subject of the hour. He spiced his remarks with vivid, dramatic experiments; for an audience "could only be induced to swallow the draught [of learning] by the honey around the rim of the cup."

Coleridge remarked that he regularly attended Davy's lectures to add to his own arsenal of metaphors. Davy's actions were as lively as his words. His movements were so quick that his classes

"believed he was preparing for an experiment when he was already obtaining the results."

Not the least of his appeal as a lecturer was the magnetism of his eyes. The ladies went into ecstasy over these "speaking eyes" which "were made for something far more than poring over crucibles." At the conclusion of one of his lectures, a woman, "well-known in the literary world," wrote him a poem. It bubbled over with tender innuendo. She enclosed with it a watch chain, begging him to wear it at his next lecture as a sign that he looked with favor upon her "bold advances."

Davy loved to be lionized. He was a provocative mixture of the chemist and the "man-about-town." Comments one biographer: "The interpreter of nature's laws during the day, in the evening he sparkled in the galaxy of society. . . . In closing the door of the laboratory, he opened the temple of pleasure."

Rarely did Davy enter his laboratory before ten in the morning, or leave it after four in the afternoon. And he never returned to an experiment once he had dressed for dinner. Yet, despite this, he managed to complete a prodigious amount of work. "No man ever had genius," he wrote, "who did not aim to execute more than he was able."

And Davy was a genius in a perpetual state of effervescence. His note books were an awesome welter of ideas. He jumbled together, "without the least regard to order," notations of experiments, phrases of poetry, plots for plays, quotations from philosophy. In the midst of his chemical research, he found time to write sections of six dramas and to attempt an epic poem in blank verse on the deliverance of the Jews from Egypt.

The physical state of his lodgings was an eloquent reflection of the turmoil of his mind. He tossed professional correspondence helter-skelter into a cupboard together with love notes from admiring ladies. In his laboratory he had half a dozen experiments simmering simultaneously. It was a scene of complete confusion. When he made an error in his notes, he corrected it

by dipping his finger into the inkwell and blotting out the phrase!

Yet "this man of slovenly habits" was the world's greatest living chemist. And his laboratory, for all its disorder, was the stage of some of the greatest scientific discoveries of all time!

IV

Davy's first great discovery resulted from his research into the nature of galvanic action. Previously, several chemists had disclosed the electric pile and had demonstrated that water could be decomposed by the passage of an electric current. Davy immediately seized upon this clue and enlarged this field of study. He demonstrated the underlying connection between chemical and electrical affinity. In so doing, he formulated the charter laws of the new science of electro-chemistry, contributing a perspective hitherto "undreamt of." His investigations form the basis of modern chemistry.

Pursuing his research with the voltaic battery, he succeeded in decomposing the fixed alkalis, and he revealed the metallic nature of their bases, giving the names "potassium" and "sodium" to the metals. That the fixed alkalis should turn out to be composed of metals was very disconcerting to some of the chemist's colleagues who had held quite contrary theories. "Really," remarked one old Scotch professor, "this Davy is a vera troublesome person."

Next he investigated the alkaline earths and reduced them to a series of metals—strontium, barium, magnesium and calcium. He found, moreover, that oxymuriatic acid was a simple substance. And he named this "chlorine" because of its greenish color.

Wherever he traveled, he took with him a portable chemical chest. And during one trip to France, he accomplished with this "streamlined equipment" an unparalleled *tour de force.* He had been requested to analyze a small sample of a substance that had been found by a soap manufacturer in seaweed. Under

certain conditions it discharged a remarkable violet vapor. Amidst the continual interruption of parties and social dinners, Davy unerringly revealed the basic characteristics of the substance. "Iodine" he called it. Within two weeks after commencing research, he collected all his material and prepared for the world a classically definitive report on iodine.

Davy's discoveries gave a tremendous impetus to industry. In fact, he played the role of a pioneer industrial chemist. And yet he refused to accept the fees offered him by manufacturers for his advice. His service to agriculture was no less significant than his contribution to industry. He was the first to convince his countrymen of the necessity of applying the methods of science to the farm. And he undertook extensive field investigations to "hammer home" the particular importance of chemistry in this connection.

He pursued his investigations to the point of exhaustion. And at one stage he fell critically ill. For weeks his life hung by a thread. And the people of England took this opportunity to demonstrate their affection for him. So great was their concern about his condition that bulletins were issued from the sick room regularly, as if he were the King. Leading physicians who treated him refused to charge a fee for their service. Fortunately for science, Davy recovered.

One factor that spurred him to such industry was his rivalry with other chemists, each of whom strove to "steal a march" on the others in publishing important discoveries. Competition between the French and British chemists took place while England was engaged in a life-and-death struggle with Napoleon. Yet despite this contention, these scientists remained entirely aloof from the jingoism that animated the armies and the peoples. The French Institute, during the height of the conflict, awarded Davy a medal for one of his experiments. Davy accepted the medal in spite of the anger of some of his countrymen. "The two governments are at war," he declared in defense, "but the men

of science are not. That would indeed be a civil war of the worst description."

Napoleon himself paid a tribute to the disinterestedness of science by permitting Davy to pass through France on a professional tour of the continent. And Davy, upon arriving in Paris, was received with enthusiasm by the savants among "the enemy."

The tour was indeed a fruitful one. From France, Davy journeyed to Genoa where he investigated the electricity of torpedoes. At Florence he conducted research into the chemistry of diamonds. He traveled to Naples to examine Mount Vesuvius during an eruption, and he commissioned one of his Italian guides to keep him posted regularly by mail on the condition of the volcano upon his return to England.

Davy was at the perihelion of his career. And he was only in his early thirties. He was knighted by the Prince Regent. (Some years later he was created a baronet.) He had married a widow, the heiress to a fortune in the West Indies, "a lioness of the first magnitude." Her name was Jane Apreece, and one of the chemist's friends quipped, on hearing of the wedding, "Davy's talents have now been fully *Apreeciated*." From the summit of his achievements, however, the chemist sighted a higher peak. And he embarked upon a discovery that added new lustre to his name.

V

IN THE FIRST DECADE of the nineteenth century, the loss of life in the coal mines was appalling. Frequent explosions were caused by the mingling of the pit gases with the flames from the miners' torches. A series of devices had been introduced from time to time in a futile effort to solve the problem. They were designed to give light with an amount of heat that would be inadequate to explode the gas. A typical contrivance consisted of a series of flints rubbed mechanically against one another. But the light was too dim to be effective.

Meanwhile the incidence of mine accidents steadily increased. Clergymen, physicians and other socially-conscious individuals embarked on a crusade to arouse the public. A committee was established to inquire exhaustively into the conditions of the pits. It returned a report that the solution to the problem of a "safety flame" must be one of a chemical nature. And it called upon the nation's leading chemist, Sir Humphry Davy, to provide the answer.

Davy accepted the challenge, and he demonstrated to the world—if any demonstration were needed—a further proof of his genius. He visited several of the pits to familiarize himself with the conditions under which the miners toiled. Then he took a sample of coal gas back to his laboratory for analysis. He found that carbureted hydrogen was the cause of the explosions, and he discovered that a far higher temperature was required to explode this than was the case with other common inflammable gases.

Furthermore, he learned that the flame caused by the mixture of the air with the coal gas would not explode in tubes of a certain narrowness of diameter, and that explosions could not penetrate fine wire gauze. Following these discoveries, he devised a series of lamps and exposed them to explosive mixtures. And from these tests the final safety lamp was evolved.

Three months after he had undertaken his investigations, Davy presented the miners with a safety lamp through which the gas from the outer air could not penetrate to the flame. The flame itself was protected by wire gauze.

Letters poured in to the chemist from miners all over England expressing amazement that so simple looking a device should "turn the trick" when the most complicated mechanisms evolved over the years had failed. One group of miners sent an especially touching note of thanks to him, expressing its gratitude for the safety lamp "which is a life-preserver for us."

Notwithstanding the claims of others to the discovery of the lamp, Davy was in fact the first to reveal its correct principle.

Although the lamp he devised was not safety proof under certain extreme conditions, the technical improvements afterwards adopted were based upon his findings. He gave the miners a safety flame which lit their lives with hope. He gave to industry one new powerful instrument to hasten its coming of age.

VI

DAVY'S LIFE was enriched by his friendships. Eminent men continually crossed his path to receive his influence and to impart something of themselves to him. While he taught at the Royal Institution, for instance, he took into his laboratory as his assistant a young book-binder's apprentice, Michael Faraday, who, under his inspiration and tutelage, blossomed into one of the great scientists of all time.

Another of Davy's moving friendships was with Sir Walter Scott, his wife's cousin. The two men regenerated the creative powers of each other. Scott's biographer, Lockhart, averred that the distinguished novelist might well have become a scientist "if he had encountered such an instructor as Sir Humphry . . . in his early life." On the other hand, under the heat of such a relationship, Humphry might have blossomed forth into an historical novelist.

Davy died at the age of fifty-one, in the prime of activity. He had lived his life to the tempo of a rapid pulse. His glands were over-stimulated. He succumbed to a premature degeneration of his nervous system.

In the autumn of 1823, he suffered his first paralytic stroke. Physicians ordered an immediate vacation. Davy set out for Italy by way of the continent in the deep of winter. To his friends he wrote despairingly, "I am leading the life of an anchorite, obliged to abstain from flesh, wine, business, study, experiments, and all things that I love."

He selected Ravenna as a place of sojourn. Ravenna, the

evening star of the ancient Roman Empire. Here he wrote poetry of "melancholy blended with resignation." At moments he entertained the idea of suicide. The flame of his life was low.

He had been compelled, due to his ill health, to resign his post as president of the Royal Society, a position to which he had been elected for seven successive years. This had been the crowning tribute of his life. Now it, too, was a memory.

His chemical researches were uppermost in his mind, even when his right side became completely paralyzed and the end was near. He wrote to his brother John, a physician, leaving him complete instructions concerning an experiment he desired him to carry out with a torpedo after he was gone. "Pray do not neglect this subject. I leave it to you as another legacy."

He died in Geneva in the month of May, 1829. His last glimpse of the world was the immortal blue of the Lake beneath the window of his hotel. And the poet within him was reassured as he looked upon the Lake.

GEORGE STEPHENSON

Important Dates in the Life of George Stephenson

1781—Born, Wylam, England.

1795—Became assistant fireman to his father.

1812—Appointed enginewright of the High Pit at Killingworth.

1814—Built the first successful locomotive for the Killingworth mine.

1815—Invented the steam blast. Devised a safety lamp for miners.

1825—Completed construction of the world's first passenger railroad.

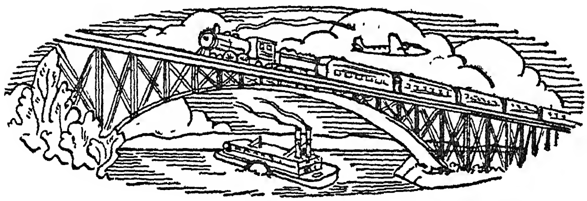
1830—Completed construction of the Liverpool-Manchester railway.

1840—Handed over the bulk of his engineering business to his son.

1848—Died, Chesterfield, England.

George Stephenson

1781–1848



IN 1825, a group of British merchants urged a bill upon Parliament to build a railroad from Liverpool to Manchester. It was an extravagant request. Most Englishmen scouted the notion that one of "those new-fangled steam engines" could run profitably upon iron rails. Railroads were the dream of a crazy mechanic! "What can be more . . . ridiculous," declared one newspaper, "than the prospect of locomotives traveling *twice as fast* as stage coaches! We would as soon expect . . . people . . . to permit themselves to be fired off upon . . . a rocket, as trust themselves to the mercy of such a machine going at such a rate!" And another journal opined: "What person would ever think of *paying anything* to be conveyed from Manchester to Liverpool . . . by a *roaring steam engine!*"

When the bill for the railroad was introduced into the House of Commons, not a single reputable engineer in England would come forward to support it—or rather, only one. He was George Stephenson, a humble miner who had risen from the pits to become an engineer. He appeared before Parliament to defend

the railroad, for it was under his supervision that the line was scheduled to be built.

It was the most terrifying moment of his life when Stephenson stepped into the witness box in the House of Commons. An impressive array of legal talent had been hired to blast the case for the railroad. Ten of the ablest barristers of England kept Stephenson under a constant barrage of cross examination. They made a huge joke out of him. Run a railroad with steam! Why it was known to every student of mechanics that a locomotive couldn't get up enough power to move in the teeth of the wind! Moreover, the weight of the engine would crush the rails to pieces.

In the face of these objections, George Stephenson remained unruffled. "*My* engine will run," he answered, and his countenance grew transfigured as if enkindled by his ideas.

"Lads," he said in his strong Northumbrian burr, "I venture to tell you that . . . people will live to see the time when railroads will become the great highways for the King and all his subjects. It will be cheaper for a workingman to travel on a train than to walk. . . . What I have declared will come to pass just as surely as you hear me today."

II

George Stephenson was a self-educated man. Born to a miner near Newcastle-on-Tyne, he couldn't read or sign his name until he was eighteen. To the end of his days he spoke with such a thick accent that it was difficult to understand what he said. Yet Stephenson was one of God's true gentlemen.

In the poisonous atmosphere of the mine, he caught the whiff of steam. And steam became his religion. For him the power that drove an engine was the force that drove the human heart. It was the sun bottled up in the earth for centuries, during which it changed its dress from the shiny beam to carbon. The steam

that propelled a human being over a railroad from Liverpool to Manchester was merely one aspect of the great over-energy which carried men from the terminus of birth to the capital city of the Beyond.

Emerson met Stephenson during a trip to England and came away remarking, "This man has the lives of many men in him!" It was no mere chance that the mystic of Concord warmed up so heartily to the mystic of Newcastle-on-Tyne.

In the deep infernal regions of the coal mine bloomed a flower—the gentle character of George Stephenson's father. Nights when he emerged from the pit, he gathered the young folk of the village around him and told them stories as bright as the fire he stoked. He spun tales of Sinbad, Robinson Crusoe and fabulous adventures of his own creation. With his sooty hands, he smoothed out nests of birds and showered a heavenful of crumbs for the hungriest of them. One afternon he brought his young son George to the home of a family of blackbirds. He lifted the little fellow in his arms and let him peer with wonder into the nest. In the bleak years that followed, poverty did not dare to rob George of his blackbirds.

He was one of six children. Education cost money, and none of the family was sent to school. As soon as George was old enough he went to work. He herded the cows that belonged to the widow of a farmer, receiving two pence a day. While keeping an eye on the cattle to see that they stayed out of the path of wagons, he scooped up clay from a bog and built model engines. He liked to believe that these toy engines were performing a man's work. And he anxiously awaited the day when he would be doing a man's job in the pits by the side of his father.

The process of digging coal and raising it above ground by ingenious mechanical contrivances enchanted him. The humming, sweating legions of toiling men were like mysterious devils with machinery more terrible than pitchforks, doing the will of

destiny in the person of the lords who owned the mines. George yearned to get into the bowels of the earth.

At fourteen he was permitted to join the miners. He entered the pits as a "picker"; that is, he cleared the coal of stones and dross. He developed such mechanical cunning that he was rapidly promoted to the job of a brakeman and then a plugman.

And yet for all his occupational success, he was unable to read or write. And this troubled him. He refused to live and die spiritually imprisoned in the pit with a mind as sluggish as a lump of coal. And so, at eighteen, he set aside a portion of his earnings and he attended night school. Three evenings a week he took lessons in reading and spelling, paying three pence for each class. By the time he was nineteen he was able to write his name accurately.

His eyes opened wide as the books he read slowly yielded their secrets. Ideas a thousand years old were dramatically new to him. He tried to transmit his intellectual experience to his brother workers but with discouraging results. Once in the pit he attempted to explain to them that the world was round, and he spun about vigorously on his feet to drive home his point. But the men laughed skeptically and declared that his information was absolutely untrue; for if the world were round, "folk on the bottom side would fall off." Henceforth, George remained isolated in the spring of his expanding universe. The acquisition of knowledge was not a social exercise.

And of all the branches of knowledge, mechanics absorbed him the most. The piston of an engine drove his imagination at a dizzy rate. It stirred him as a poem stirs the poet.

Nor did he scorn to apply his talents practically. In his spare time he learned to mend shoes, and he supplemented his earnings in this fashion. On one occasion, during his absence, the chimney of his cottage caught fire. His neighbors poured buckets of water into his parlor, drenching, among other articles of furniture, a highly-prized clock. Unwilling to pay money for

repairs, George examined the mechanism himself and fixed it so successfully that his friends sent him their broken timepieces. He became famous as a "clock doctor."

Twice tragedy overtook him. Fanny Henderson, a farm servant who became his wife, died of consumption, leaving him with a young son. George's father was struck in the face by a blast of steam and lost his eyesight. He retired from the pits, and George supported him for the remainder of his life.

More trouble came his way. The British Government, in the throes of war with Napoleon, passed a military draft law. And the young miner was drawn for service. But since he was the sole support of two dependents, he seized upon an alternative to service. He bought a substitute for the draft and thereby exhausted his meager savings.

The war had raised the cost of living to such extravagant heights that for a time he toyed with the idea of emigrating to America and finding a job that would enable him to support his father and his child decently. But since he couldn't scrape together sufficient funds for the trip, he remained in England to weather the storm.

And eventually the horizon cleared. His reputation as a mechanic was dramatically publicized to the executives of his mine when, on one occasion, an engine failed to pump water from a pit. None of the salaried engineers were able to diagnose the trouble. George volunteered his services. And the supervisor accepted them. He took the machine to pieces, repaired it and within three days he had the entire pit cleared of water. As a reward he was advanced to the position of general engineer at the salary of a hundred pounds a year.

George's relatively comfortable income inspired new ambitions in him. Determined that his growing son, Robert, should not be handicapped by a lack of education, he sent him to school. And he took advantage of this to add to his own fund of knowledge. Robert brought back a summary of all the books he had read in

the library, and together with his father he studied the material evenings before going to bed. Later when he grew older, Robert was enrolled at the University of Edinburgh where he transcribed his lectures in natural history, philosophy and science for the edification of his father.

In step with this continual struggle to acquire an education, George Stephenson, in his duties as engineer, undertook epochal experiments which were destined to revolutionize the transportation system of the world.

III

The rapid expansion of the mining industry at the beginning of the nineteenth century brought about a demand for more efficient methods of hauling coal from the pits to the shipping markets. Horses were customarily employed to pull the loads. But due to the Napoleonic wars, the price of corn—horsefeed—had become outrageously high.

From the days of Watt, inventors had speculated about the possibility of harnessing steam to carriages for carrying goods and passengers. One chap by the name of Trevithick had succeeded in building a clumsy steam engine designed to run on cast-iron rails. But during a test, the engine crushed the rails into fragments.

Scores of other mechanical minds grappled to solve the problem, and several freak "locomotives" were unveiled. An inventor actually devised a locomotive which "walked on iron legs," in the manner of a horse. But it met with a tragic end. "At its first trial," recounted an eyewitness, "the driver, to make sure of a good start, overloaded the safety valve, whereupon the boiler burst and killed a number of bystanders, wounding many more."

Such was the state of affairs when George Stephenson turned his attention to the problem. He made a thorough study of the engines thus far constructed to discover why they had failed. Practically every one of the inventors had labored under the

delusion that their engines could not obtain a "bite" upon the smooth rails unless the wheels were built with "teeth." Stephenson made careful experiments and concluded that the adhesion between the wheels of a loaded engine and the rails was of itself sufficient to insure friction, hence forward progress, without the employment of "teeth." Providing the rails were sufficiently strong, there was no limit to the speed that a properly-built engine could attain. And George Stephenson was convinced that he could develop the correct engine.

The chief problems were to find sufficiently skilled mechanics to carry out his plans, and to attract adequate funds for the enterprise. He solved both. He obtained money from the lessees of his mine, and he trained mechanics to employ the relatively primitive tools then in use in the pits to turn out an entirely new kind of machinery.

On July 25, 1814, Stephenson placed his locomotive on the rails for its initial run. "Blücher—named after the hero of Waterloo—successfully carried eight wagon loads of thirty tons' weight at the speed of four miles an hour. Yet it was a clumsy vehicle for all its improvement over previous engines. It puffed forward in spasms of jerks and jolts.

Stephenson completely overhauled the mechanism and surmounted a technical obstacle that hitherto had prevented the locomotives from becoming a commercial success. On February 28, 1815, he took out a patent for a steam blast, a key part for all future locomotives. He hit upon the tremendous principle of applying the waste steam of the engine (which none of his predecessors had thought of doing) to increase the intensity of combustion in the boiler, and thus develop the power of the engine. The invention of the steam blast led to the evolution of devices by others which made possible high rates of speed. Lacking these, locomotives would have gone chugging along at the rate of six miles an hour.

At the same time, Stephenson turned his attention to the iron

rails. He developed a method of laying the tracks by which they overlapped one another "like a scarf-joint." And over them his engine ran with satisfactory smoothness.

Few people, however, took the Newcastle engineer seriously. Even his neighbors didn't consider "Puffing Billy," his locomotive, to be anything more than an ingenious, though limited, device for carrying several wagon loads of coal. It never occurred to the wildest-eyed of them that passengers would someday be driven by the descendants of "Puffing Billy" from one end of the world to the other.

An obscure mine engineer who possessed no "connections," Stephenson was unable to bring his locomotive dramatically to the attention of the general public. He hadn't the eloquence to trumpet his achievement, to give tongue to his vision.

Nevertheless, a handful of mine operators, while they could not understand the vaster implications of Stephenson's locomotive, at least appreciated its proven efficiency in hauling coal. They commissioned him to build them engines similar to "Puffing Billy." The years passed slowly. Then, finally, a long-awaited opportunity arrived.

A group of Quakers petitioned Parliament for permission to build a horse-drawn railroad from Stockton to Darlington in the north of England. Stephenson, hearing of the petition, called upon the promoters, who after witnessing a demonstration of his "Puffing Billy," decided to purchase a locomotive to haul freight. However, no Englishman would as yet entrust his life to a steam engine; and so horses were employed by the Quakers for the passenger traffic.

The Stockton-Darlington Line was opened to the public in 1825. The logic of history was with Stephenson. The industrial conditions of England made it inevitable that his great vision would eventually be realized to its last detail.

At that time the bulk of commercial freight was carried by ship through canals. The private canal companies, virtual monopolies,

charged exorbitant rates. And they conducted business in a lazy, inefficient fashion. Leading merchants of Manchester and Liverpool, seeking a speedier and more efficient route for their merchandise, formed an association to build a railroad connecting their two cities. Learning of George Stephenson's success with the mine railways, they asked him to supervise the construction of their projected road.

An unbelievable storm of protest followed the announcement of the company's plans. Influential landowners, who fancied that their privileges would be invaded by the laying of rails adjacent to them, mobilized to oppose the surveying. Businessmen who had invested heavily in turnpike roads joined the landowners in opposition. The canal companies, fully aroused to the danger of competition, entered the struggle. They launched a nationwide campaign in the press to vilify the railroad.

They hired journalists to describe the catastrophe that would overtake England if iron tracks were allowed to "besmirch her verdant fields." They claimed that the "railways would prevent cows from grazing and hens from laying eggs." They warned folk along the projected line that their homes would be burnt to the ground by the fire thrown up from the stacks of the steam engines. They vowed that once the railroads "got a foothold" in the nation, horses would become extinct; farmers would be unable any longer to market oats and hay. They frightened the general public—the future passengers of the railways—with the prospect that travel by locomotive would imperil their lives; that "the boilers of the engine would surely burst and blow them into fragments."

So cunningly did the vested interests arouse the fears of the people that Parliament at first rejected the bill for the railroad. But the promoters were adamant. They induced leading landowners to take substantial shares in the line. By virtue of this and similar measures for buying off the opposition, the promoters ultimately won a favorable vote in Parliament.

Stephenson, as engineer for the railroad, faced what many

experts believed to be an impossible assignment. Towards one end of the thirty-mile stretch between the two cities, there was a peat bog about twelve square miles in extent. Qualified engineers asked themselves "how in thunder" Stephenson proposed to construct a railroad for a locomotive and a trainload of passengers over a bog that was unable to support the weight of a single man!

His solution was an ingenious one. He planned to *float* a road over the bog. Just as a heavily-loaded ship rides the water, so a locomotive could be driven over the bog if its bearing surface were extended and its pressure were distributed over the entire area upon which it stood.

Stephenson dug drains along the sides, prepared a foundation of "basket work," holed up the interstices with moss, and placed over it a layer of clay and soil. Patiently he filled in the layer of the bog until the embankment rose to meet the surface soil. In this fashion, almost seven hundred thousand cubic yards of moss were compressed into two hundred and seventy thousand cubic yards of embankment. "The result resembled a long ridge of tightly pressed tobacco leaf."

Stephenson overcame other obstacles along the route by equally spectacular means. He tunneled under Liverpool for a mile and a half to complete one of the terminals. He scooped two miles through the rock of a mountain. He built sixty-three bridges over the thirty-mile line.

As the project neared completion, the owners held a competition to choose the locomotive with the best performance for their road. Stephenson entered "The Rocket" which triumphed over all its rivals, reaching a speed of twenty-nine miles an hour!

The railroad was inaugurated on September 15, 1830. A huge crowd which included the Duke of Wellington, the Prime Minister and other dignitaries of the Government assembled for the ceremony. The following morning the line was opened officially to the public, and the initial passenger train carrying one hundred and forty travelers completed the trip on time. England's first

locomotive-run passenger railroad had been successfully established, thanks to the perseverance of a miner who refused to concede defeat.

IV

In 1833 the French Government actively began the development of nationwide lines. Two years later the first German railway was opened to the public. The United States had leveled its initial rails some years earlier. By the middle of the century railway projects were fairly well advanced in most of the civilized countries of the world.

The building of railroads is one of the most inspiring chapters in the history of every nation. A new type of worker, the railroad crewman, came into being. In England these crewmen were called "navvies." They assembled from all over the country and spent years on each construction project, working as much as sixteen hours a day. The feats they performed were epic. Water was the great foe of railway engineering. Along one stretch these "navvies" worked steadily for eight months pumping two thousand gallons of water a minute from a sand bed. One historian estimates that the work expended on the London-Birmingham railroad was twice the labor that went into the construction of the Great Pyramid in Egypt.

A great financial boom accompanied the expansion of the railroads. People speculated hysterically in railway shares. Gamblers and crooks flourished by the side of legitimate constructors. Members of Parliament pressed bills for speculative lines in which they were financially interested. The mania reached immense proportions. "If necessary," declared one marquis to a group of investors, "I shall dig a tunnel beneath my drawing room!"

Meanwhile, George Stephenson, the inventor who had made railroads possible, was one of the busiest engineers in Europe. He supervised railroad construction all over the continent. And he

continued to improve his locomotives until he finally developed one that reached a speed of eighty miles an hour.

He never lost his taste for the humble, holy things. Amidst the rush of business he found time to write his son a touching letter concerning a pair of robins who had built their nest in one of the upper rooms of his house. Human misery was personally real to him. Some years before he became famous, he had been so deeply affected by the continual round of mine explosions that, at the risk of his own life, he conducted experiments in the midst of the poisonous gases of the pit and devised a "Geordie Safety Lamp," by whose light the miners could work with safety. Although it was not as celebrated or as scientifically accurate as the lamp Sir Humphry Davy invented at about the same time, it nevertheless won the gratitude of the workingmen for miles around.

At sixty Stephenson handed over his business to his son, Robert, whom he had trained to become an eminent engineer in his own right. He retired to a country estate near Chesterfield, where he grew pineapples as large as pumpkins and grapes that took national prizes. He passed away in 1848 in his sixty-seventh year.

To the end George Stephenson remained a workingman; so much so, that he refused to be knighted by the Queen. One knighted by God had no need to be transformed into an artificial gentleman.

Miners followed his coffin to its resting place. Appropriately enough, the finest statue erected to him stood in Newcastle-on-Tyne near his locomotive factory, in the center of a thoroughfare traversed by the workers who looked into his face as they walked to the pits.

LOUIS J. M. DAGUERRE

Important Dates in the Life of Louis Jacques Mandé Daguerre

1789—Born, Cormeilles, France.

1822—Opened the Diorama in Paris, an exhibition of pictorial views.

1829—Collaborated with Niepce to produce "heliographic pictures."

1833—Niepce died. Carried on investigations alone.

1839—Announced iodine process for printing photographs. Appointed an officer of the Legion of Honor. London Diorama destroyed by fire.

1851—Died, Petit-Brie-Sur-Marne, France.

Louis Jacques Mandé Daguerre

1789–1851

ABOUT 2400 YEARS AGO the Greek philosopher, Aristotle, observed that when "the sunlight enters through a tiny hole in the wall of a darkened room, it casts on the opposite wall an inverted image of the scene that lies outside the hole." The image is inverted, as he pointed out, because the rays of the light travel from the scene to the wall-screen in straight lines. Thus, the light from the *top* of the scene passes downward through the hole to the *bottom* of the wall; the light from the *bottom* passes upward through the hole to the *top* of the wall; the light from the *left* travels to the *right* of the wall; and the light from the *right* travels to the *left* of the wall. And thus the reflected image becomes topsy-turvy; it appears to "stand on its head."

This observation of Aristotle's is the first historic mention of the *camera obscura*—the principle of the *darkened chamber* with a tiny hole in one of the sides to allow for the penetration of the light. The Greeks of Aristotle's day were thus crudely aware of the idea of *photography*—the delineation of images through the agency of the light.

But they knew nothing about the principle of *arresting* an

image and *imprinting* it for future contemplation. This principle was to remain a secret for over 2000 years. At the beginning of the sixteenth century the Italian painter, Leonardo da Vinci, wrote about the "marvels" of the camera obscura. But he too, like Aristotle, regarded this instrument merely as a "reflector" and not as a "perpetuator" of landscapes and persons. Up to that time the camera was literally a dark room, occupied by a draftsman who traced the outlines of the projected image and thus was able to get an accurate drawing of the object that produced the image.

The oversized camera of that period served not only as a workroom for draftsmen but as a showroom for magicians. These "jugglers of magical scenery" enacted their shows outside the camera, while the audience, seated inside, marveled at the "moving pictures" projected upon the screen in front of them.

In order to straighten out the inverted images for their audiences, the magicians began to experiment with mirrors placed at various angles. And in order to sharpen the images upon the screened wall, they adopted lenses of various shapes and sizes. And thus the camera had now (in 1568) become a large, dark room fitted with a lens to focus the rays of the sun.

But a large room was too clumsy an instrument for the various uses to which the camera was now being put. The artists especially found themselves in need of a smaller "projection room" which could be carried about from place to place. Hence the evolution —in the seventeenth century—of the portable camera. This small "picture box" was fitted with a carrying-handle, a lens in the front wall, and a transparent screen in the back wall. The artist, as he watched the reflection of the landscape upon the transparent screen, was covered—like the photographer in a modern studio—by a dark hood to keep out the sunlight between himself and the camera. And thus protected, he painted upon his canvas the landscape as depicted upon the screen.

But still there existed no method for preserving the images that were reflected through the lens of the camera and depicted upon

the back wall. When the face of the camera was moved away from a certain object, the image of that object was forever gone. The art of permanent photography—of translating the sun's writing into a legible and durable record—had not as yet been born.

And then, in 1727, a chemist by the name of Johann Schulze made an important discovery. He noted that the action of light can produce a radical effect upon silver salts. This discovery was the final stepping-stone to the invention of photography. For modern photography is a two-fold process: the *projection* of an image through the focusing of the light, and the *preservation* of the image through the reaction of the light upon certain chemicals.

But it took the world another hundred years to catch up with this idea. Throughout the balance of the eighteenth century, the scientists experimented either with the one or with the other of the two photographic properties of light. Some of them developed the camera; others made impressions of ferns and engravings, without the aid of a camera, upon paper or glass sensitized with silver nitrate. But nobody thought of *combining* these two processes into the invention of a new art.

Moreover, the impressions that were made upon a sensitized surface were only temporary. In 1802, Thomas Wedgwood and Sir Humphry Davy wrote a paper on the virtues and the defects of "imprinting profiles by the agency of light upon nitrate of silver." These "profiles"—or pictures—had to be kept in the dark; for they faded out when exposed to the light. "It is an elegant process," wrote Sir Davy, "but it can subserve no useful purpose."

And thus the scientists kept literally groping in the dark, catching here and there a glimpse of light but unable to coördinate these abortive glimpses into a definite vision—until Louis Daguerre came upon the scene. It was his patient experiments that finally succeeded not only in *capturing* but in *perpetuating* "the handwriting of the light."

II

DAGUERRE, the son of a court-clerk at Cormeilles, in the province of Seine-et-Oise, showed an early aptitude for art. He loved to paint the countryside, especially at dawn, when the light "etches, as with a delicate pencil, the outlines of the awakening world."

As a young man, he went to seek his fortune in Paris. Here he studied the art of stage lighting and scene painting at the studio of the famous Degatti. "You've got the magic touch, Daguerre," said his teacher. "There's nobody else in France who can so faithfully reproduce the very breath of nature."

To reproduce the breath of nature. To transform light into life. He would dedicate his entire ambition to that end. Always he experimented—on the stage and in his own room—with bits of scenery set at various angles, and illuminated by novel combinations of colors. An inventive artist. A new "Daguerre setting" in the theater came to be as eagerly awaited as a new play.

And then, one day, he went to see a panorama—a painting of the countryside on a huge canvas arranged on rollers so that the picture kept unfolding before the eyes of the spectators. It was like traveling in a carriage over the highway, this continual shifting of the scene in front of you. The trees, the cattle, the river, the clouds, the farmers at the plow, the church steeple above the horizon—a veritable moving-picture of the world. But it was the picture of a *dead* world. "If only I could do something to bring this painted scenery to life!"

How about *repainting* such a scene so that it would actually *imitate* life? Through the interplay of the various lights and shadows upon it—just as in the real world. The rose-tinted rays of the morning, the noonday glare of the sun, the shimmering haze of the twilight, the black-and-silver etching of the night.

He began to work upon this idea—and under the magic of his touch the panorama developed into a new form of art. An inven-

tion of his own, in collaboration with a fellow-artist, Bouton. The *diorama,* a translucent sort of panorama painted on both sides of the canvas—a picture that you could look not only *at* but *through*. And this translucent quality gave the picture a three-dimensional aspect; so that when you witnessed a diorama, you saw "the forces of creation at play."

They exhibited this diorama—a succession of several paintings—at the "Hall of Miracles." And they performed these miracles of "an imitation of nature as natural as life itself" by a "secret process of illumination." One of the spectators at the exhibition wrote to his son that "nothing in the world is superior to a couple of the views painted by Daguerre; one of Edinburgh, taken by moonlight during a fire; the other of a Swiss village, looking down a wide street, facing a mountain of tremendous height covered with eternal snow. Those representations are so real, even in their smallest detail, that one believes that he actually sees rural and primeval nature, with all the fascination with which the charm of colors and the magic of light and shade can endow it. The illusion is so great that one even attempts to leave his box, in order to wander out into the open and to climb to the summit of the mountain."

The man who wrote this letter about the diorama was Joseph Nicéphore Niepce—a country gentleman who was to play an important part in Daguerre's invention of photography.

III

DAGUERRE'S SCIENTIFIC INTEREST in photography stemmed from his artistic preoccupation with light. If light can be projected to *illuminate* a picture, maybe it can be directed to *paint* a picture. "A picture painted by the sunlight, guided by the finger of God, would be ever so closer to nature than the silly imitations of any human painter."

And so he began to experiment with photography—the produc-

tion of pictures through the action of light. Though he knew little about science, he was sufficiently aware of the two requisites for the making of a good photograph:

1. An object with a flat surface—such as a metal plate for example—must be coated with a light-sensitive chemical and placed inside the camera.

2. When the image has been imprinted upon the plate, it must then be removed from the camera and subjected to another chemical in order that the imprint may become permanent.

It was along these two lines that he conducted his experiments. After a considerable number of trials and failures, he learned that he could imprint a rather indistinct image upon a silver plate that had been coated with the vapor of iodine. But in order to produce the image of an object, it was necessary to expose the object for several hours—a slow and unsatisfactory process in the case of natural scenery, and a practical impossibility in the case of living sitters.

But he kept doggedly at the job, neglecting his interests in the diorama, forgetting his family—he was married now—and "wasting away his affections and his fortune," as his wife complained, "upon the hazy images of a dead world." Frequently he forgot his meals; and when his wife came into the studio to call him to the table, she found him "immersed in a bath of malodorous vapors." She began to fear for his sanity—"no man in his senses will surrender himself to *that* sort of stupidity"—and she went to consult Professor Jean Dumas, of the *École Polytechnique,* about the advisability of committing her husband to a lunatic asylum. But the professor, after a visit to Daguerre's studio, advised Madame Daguerre to leave her husband alone. "Monsieur is on the way to a great discovery. To interfere with him now would be interfering with the progress of the world."

From that time on, Madame Daguerre carried no further tales about her husband's insanity. She kept her conviction on this point to herself.

And her husband plunged more enthusiastically than ever into his laboratory fumes and his hopes.

And the baffling continuity of his failures. One of his chief troubles was that he couldn't get a clear image on his plates, no matter how long he exposed them. One day, after a long succession of unsuccessful experiments, he took out an exposed plate from his camera. It showed no image whatsoever. In sheer disgust, he put the plate into a closet to be re-coated for a new exposure on the following day.

The next morning, when he took the "ruined" plate out of the closet, he was amazed to find a distinct and beautiful picture upon it.

How did it happen? By what strange sorcery had the unsuccessful exposure become transformed into a successful picture? He looked at the various objects in the closet. No apparent clue there. An accident? He would try and see. That evening he placed another "underexposed" plate, showing no trace of a design, into the selfsame closet. The following morning, another beautiful image, imprinted in clear outline to the minutest detail.

It was no accident. The closet was being used as a storeroom for the various chemicals with which Daguerre had been experimenting. Apparently it was one of these chemicals that had produced the miracle.

But which one? Another protracted series of experiments, until nearly all the chemicals in the closet had been exhausted—and the solution seemed as far away as ever.

And then, as he was about to give up, he noticed a dish of mercury that he had overlooked in a dark corner of the closet. With no hope of success, he took an exposed but imageless plate and held it over the dish.

And the miracle happened again. Little by little, the picture emerged in distinct outline. It was the vapor from the mercury that brought out the image through its absorption into those parts of the plate upon which the rays of the light had been focused.

And thus Daguerre was now in possession of about two-thirds of the secret of photography—how to produce a latent image through the focusing of the sunlight upon a plate coated with the vapor of iodine, and how to bring the latent image into clear visibility through its exposure to the vapor of mercury. But all this procedure resulted in a *temporary* picture which had to be kept always in a dark place.

And now for the final and most difficult step in the process—how to make the picture *permanent* when brought into the light.

It was at this juncture that Daguerre met his future collaborator, Nicéphore Niepce.

IV

In the course of his experiments, Daguerre bought his plates and his cameras from an optician by the name of Chevalier. Without disclosing the secret processes of his discovery, he frequently discussed his general problems with the optician. One day Chevalier suggested that Daguerre might find it advisable to communicate with Niepce—another of his customers who dabbled "in the art of sun-painting." M. Niepce called his process *heliography.* He, too, complained of his many difficulties. "Perhaps, if you met him, you could iron out your difficulties together."

Daguerre accepted the suggestion. He wrote a letter to Niepce, and received no reply. He waited for an entire year, and then he wrote another letter. This time the reply was prompt and enthusiastic. "When I first heard from you, I said to myself, 'Another of those cranks—perhaps charlatans—who are trying to pull the worms out of my nose.' But I have since heard many flattering things about you. And I have seen your wonderful diorama. I shall be very happy to make your acquaintance and to talk with you about our mutual interests."

They met, and formed (in 1829) a partnership for the further

Humphry Davy

George Stephenson

"examination and exploitation of the secrets of sun-painting."

Niepce, like Daguerre, had been experimenting with the reaction of light upon various chemicals. "I am trying to etch by means of the sun—to use its rays like the bristles of a paintbrush with a coated plate for a canvas." But the coating of his plate—a chemical known as *bitumen of Judea*—was inferior to the vapor of iodine as used in Daguerre's pictures. In this respect, he was a step behind Daguerre. In another respect, however, he was a step ahead of Daguerre. For he had discovered a process for the imprinting of his temporary images into permanent pictures through the immersion of his bitumen-coated plates in a bath of lavender oil. The property of this oil was such as to dissolve all the bitumen on the plate with the exception of those parts that had been touched by the light. And thus the sun-painted image stood out upon the plate while the rest of the coating became obliterated.

With these various processes as a starting point, the two partners went ahead with the experiments in the direction of a "clearer and more lasting light."

V

THEY CONTINUED their researches, with little further result, for four years; and then Niepce died (in 1833), leaving Daguerre once more to his own resources. But Daguerre, out of generosity, took Niepce's son into the partnership and gave him a fifty-percent share in the business.

Another six years of struggling—all outgo and no income on his still unperfected pictures—and the loss of his only other source of support. His diorama was destroyed by fire.

And then, the dawn. "I have seized the light, and made it forever my slave!" At long last he had discovered the one chemical—sodium hyposulphite—which could most effectively wash away the untouched portions of the plate and thus bring into the clear the portions painted into a picture by the sun.

This discovery of sodium hyposulphite—the "hypo" of modern photography—as a washout for the superfluous chemicals of a photograph was the final step in the invention of the daguerreotype.

The daguerreotype, it must be noted, is not to be confused with the modern photograph. The photograph is a picture imprinted on *paper*—a process evolved by the British scientist, Talbot Fox. But the daguerreotype is an image depicted upon a *metal plate*—the first successful example of sun-writing aided by chemicals designed to "imprison the light."

And this imprisonment of the light through the discovery of Daguerre was hailed as one of the wonders of the world. He made the first public demonstration of his process, at the Palais Mazarin, on August 19, 1839. A host of people had crowded inside, and an even greater throng was clamoring outside for the earliest news of the experiment. A tumult of impatient curiosity. Several of the spectators were hurt in the scuffle and had to be taken to the hospital. At last a man rushed out of the building. "The miracle has happened! The reign of art is at an end! From now on, we shall have but a single artist—the Sun!"

No less enthusiastic than the general public was the press. An American reporter, who was present at the demonstration in the Palais Mazarin, wrote to his paper, the *New York Star:* "I never saw anything more perfect than that picture, literally painted by the sun." A French journalist observed that "from now on the artists, spurred by their competitor, the sun, will be compelled to tell the truth." And another journalist called photography "the creation of God enshrined on a silver plate."

But above this chorus of acclamation, there arose a few notes of bitterness and dissent. "The sun, as it paints the picture," complained Honoré Daumier, a professional artist, "demands too much patience from the sitter. And patience," he added, "is the virtue of an ass." Another artist hung out a sign in front of his

studio: "Your portrait in 13 minutes—without the help of the sun."

But the most astonishing criticism of photography appeared in a German paper, the *Leipziger Anzeiger:* "The new invention is blasphemous. For man is the image of God, and you can't imprison God in a little black box."

VI

IN SPITE OF the few sour notes against Daguerre's invention, "all Paris—and soon the entire civilized world—rushed to the optical shops to buy cameras and lenses." But Daguerre derived no great profit from his art. He presented his patent to the French government, "for the public good," and received in return a pension of 4000 francs a year. He asked that a similar pension be given to Niepce's son. The government granted the request, but added 2000 francs to Daguerre's annuity, "in consideration of his other gift to the world—the diorama."

And so Daguerre was assured of 6000 francs a year for life, just enough for a comfortable old age free from those two equally abominable diseases—the excesses of luxury and the extremities of want. He retired to his native village and devoted the rest of his days not to photography but to his earliest love—painting. He decorated the village church with an apse whose colors and vaulted scenery "were so lifelike that it was impossible to tell where reality ended and the painting began."

And thus the inventor of photography stepped out of the sun into the shadows, while others profited by his ideas and basked in his light. A schemer by the name of Disdéri, for example, became the court photographer to Napoleon III and averaged in a single day as much money as Daguerre received in an entire year.

But Daguerre was content. "A frugal meal, a smiling landscape, and a paintbrush in the hand—what greater blessings can heaven bestow upon *any* man?"

SAMUEL F. B. MORSE

Important Dates in the Life of Samuel Finley Breese Morse

1791—Born, Charlestown, Mass.

1810—Graduated from Yale.

1811—Became the pupil of Washington Allston, the painter.

1825—Organized an association which became the National Academy of Design.

1832—Completed first rough draft of the telegraph.

1837—Exhibited first successful telegraph apparatus at the New York University building.

1842—Laid the first submarine telegraph line.

1844—Sent first message by telegraph from Washington to Baltimore.

1847—Successfully defended in court his claim to be called the inventor of telegraph.

1858—Received a sum of two hundred thousand francs appropriated jointly by the leading countries of Europe in recognition of his invention.

1872—Died, New York City.

Samuel Finley Breese Morse

1791–1872

UP TO THE AGE OF FIFTY, Samuel Morse's vocation was painting; invention was merely his pastime. Yet he allowed his pastime to interfere with his vocation to such an extent that for a number of years he barely managed to make a living. He was teaching art classes at New York University. His salary consisted of the fees paid him by his students. One of the students was behind in his quarterly payment of fifty dollars. "Strothers, my boy," said Morse, "when do you think I can expect the money?"

"Next week, Sir, maybe."

"Next week," smiled Morse, "I shall probably be dead."

"Dead, Sir?"

"Yes, of starvation."

The student managed to scrape together ten dollars and handed them to Morse. "Will this do?"

"At least it will save my life for the present." And then, on a sudden impulse, "I want you to be my dinner guest tonight."

"But, Sir, can you afford it?"

"Of course I can! Haven't I got ten dollars?"

When the dinner was finished, Morse remarked casually, "This is the first meal I've had in twenty-four hours."

He might have made enough money on his paintings—he had won plenty of honors for them—had he devoted all his time to his art. But he "wasted away his precious hours"—so his friends said—on his "worthless" scientific experiments. One day a student was looking for lodgings at the university. The janitor showed him into a room full of paintings and statues and cobwebs. "If you take this room," said the janitor, "you'll have an artist for a neighbor. A right good artist, too, they tell me. But too damn shiftless. Wastes all his time over some silly invention. A sort of wire, he says, that'll carry messages from one city to another. Cracked in the head, if you should ask me."

And this was the verdict of many a wiser man than the janitor. When he presented the idea of his telegraph to the United States Congress (in 1843), one of the members—Senator Smith of Indiana—studied Morse's face, as he confessed afterwards, "for signs of insanity."

Yet Morse was one of the sanest of men—a typical American of the nineteenth century.

II

THE AMERICANS in the nineteenth century were among the most energetic adventurers of history. Having started on their adventure several hundred years after their European brothers, they seemed to be forever trying to catch up with time. Every visitor from the Old World was struck with this rapid and almost feverish pulsation of American life. "In America," wrote one of the tourists, "there is no such thing as rest. The Yankee is a machine of perpetual motion. When his feet are not moving, his fingers must be in action; he must be whittling a piece of wood, cutting the back of his chair, or notching the edge of the table . . . always making things for ornament or use . . . and always in a

terrible hurry to get things done . . . likes to try his hand at everything, and does most things well."

Samuel Morse was a man of this energetic stamp. A restless, imaginative, tenacious, precise and prolific type of mind. An all-round character whose intellectual windows were open to every phase of human activity. An artist in his science, a scientist in his art. He tried to be a painter, but his paintings brought him more glory than gold. His countrymen were in the process of building; no time for embellishment as yet. America needed inventors, and not decorators. The structure of America was becoming too complicated and too vast. The nation was spreading out too rapidly, and communication between the government and the people was too slow. The body of America was stretching too far away from the heart; and the problem of keeping the country physically and mentally united was becoming daily more difficult. Something must be done to eliminate the enormous distances of America and to bind the people into one.

And Morse, who was sensitively alive to the spirit of the times, diverted his genius from the creative reproduction of nature to the practical elimination of space.

III

Both by training and by temperament, Samuel Morse was a creative artist. Born in Charlestown, a suburb of Boston (April 27, 1791), he was only four when he made his first drawing—a pin-picture of his school teacher scratched on a chest of drawers. His reward for this artistic effort was a caning. A funny world, the little artist must have pondered, where beauty is repaid with blows.

He received little further encouragement for his subsequent attempts at portraiture—sketches of the picturesque characters along the Charlestown water front. His father, the Reverend Jedediah Morse, frowned upon these pictures and tried his best

to dissuade his son from so unprofitable a career. America had neither the taste nor the time to spend money on pictures. Besides, artists were such an unholy lot. If Finley—the name by which he was familiarly known—was destined to be a *poor man*, let him at least be a *clergyman*. And so the good priest sent his boy to Yale, his own Alma Mater.

Here the young student neglected his classical studies, took an interest in the lectures on electricity, and devoted all his spare time to painting. His fellow-students, delighted with his work, showered him with orders for their "profiles"—at a dollar a piece.

And the young artist, delighted with his "success," was now more determined than ever upon his career. "My passion for art," he wrote to his parents, "is so firmly rooted that no human power can destroy it . . . Without it, I am sure I should be miserable."

The black sheep of the family. Too bad he couldn't be steered, like his two younger brothers, Sidney and Richard, into a *respectable* sort of education. But there was nothing to be done about it. Perhaps it was the will of God that Finley's wastefulness should serve as a spur to his brothers' assiduity.

And so, with great reluctance, his parents consented to his artistic "whims"—especially when they observed that, in spite of his painting, he clung tenaciously to his orthodox creed. The *Calvinist* creed.

They allowed him to study under Washington Allston—"a rare combination of respectability and genius." Together the famous artist and his pupil went to London. It was a time of stirring events and enthusiastic ambitions. Wellington had just defeated Napoleon; the world—as everybody believed—was safe for democracy; and youth was attuned to victory. Morse painted steadily and dreamed great dreams. He had genius—Washington Allston and another great American artist, Benjamin West, had told him so. He would settle down in England, and conquer the world with his brush just as Wellington had conquered it with

his sword. He painted a picture of the *Dying Hercules*—a canvas of colossal size. From the very outset, Samuel Morse had grandiose ideas. His imagination roamed over vast horizons. He could conceive nothing on a small scale. In his artistic, as in his scientific conceptions, he had the vision of a superman.

The *Dying Hercules* won him a gold medal from the British Society of Arts, and a glowing eulogy from one of the English critics who placed him in a class with Wilkie and Lawrence and Turner.

But this, for the time being, was the end of his conquest. In spite of his enthusiasm and his ability, he was unable to sell any of his paintings in England.

Disgusted with the indifference of the public, he returned to America. His confidence had given way to anxiety. He was overburdened with a sense of his failure. Yet—romanticist that he was—he married and began to raise a family.

For a time his marriage brought him a measure of luck. He became an itinerant artist—that is, a "peddler of painted faces." He traveled from town to town, and took orders to paint portraits at fifteen dollars a head. His orders and his prices increased so rapidly that by the time he reached South Carolina, he was able to charge his sitters as much as sixty dollars a picture. His wife thought that this prosperity was too good to be true. And it was. Encouraged by his success, everybody in Charleston became an artist and began to paint everybody else. Waiters, barbers, tailors, cobblers and cooks—all sorts of people with or without jobs—suddenly threw themselves into this new profession. Mediocrities transformed into masters, offering their "divine inspiration" at any price that would buy a meal.

So keen was the competition, and so eager were the rivals to underpaint and underbid him, that Morse was compelled to shake the dust of Charleston from his well-worn shoes and to try his luck once more in the North. In addition to his wife, he now had three children to support. For a while he continued with his

painting and with the feeding of his family on his enthusiasms and his dreams. Patiently his wife waited for their "ship to come in." But she never lived to see it. Worn out with hunger and worry, she succumbed to tuberculosis—the scourge of the poor.

Two of his children had preceded his wife. All his dreams thus far had ended in despondency and death.

But there was no end to his dreaming. "I've still got it in me to conquer the world!" For his guiding star had begun once more to tantalize him with visions of success. His canvases had begun to sell for a while. He painted a portrait of Lafayette, who was visiting America; of President Monroe; of Noah Webster; of the inventor, Eli Whitney; of the poet, William Cullen Bryant; of Philip Hone, the mayor of New York. He was thirty-eight years old now. Touches of gray at the temples. Deepening of the lines around the mouth. Half a life completed, and a reputation still on the rise. One of the leading artists in the United States.

Not enough, though, for the fulfillment of his dream. He wanted to be recognized as one of the leading artists in the world.

And so, another trip to Europe—for the further *perfection* of his art and, though he was unaware of it at the time, the experience that was to lead to the final *desertion* of his art.

IV

ON HIS SECOND TRIP to Europe, he visited not only England but the Continent as well. Here he examined the old masters and made a scientific study of the colors and the designs that rendered their paintings so pleasant to the eye. Like Leonardo, he believed that esthetic harmony was based upon mathematical form.

As a result of his studies, he experimented with new patterns in draperies and new tints in flesh. His paintings, based upon these experiments, were as beautiful as they were startling. Morse was well on the way to becoming one of the foremost painters of the century.

Yet busy as he was with his painting, he found time to take an active part in the politics of Europe. Brought up in an atmosphere of freedom, he looked with admiration upon those of the Europeans who were fighting against tyranny. He joined a committee that was trying to champion the Polish struggle for independence. And he helped to bring about the liberation of Dr. S. G. Howe, an American who had collected a sum of money for the Polish fighters and who had been arrested in Germany.

And, in addition to all his other activities, he kept himself informed on the latest developments in science. "For I am an American, and hence every human endeavor lies within the scope of my interests." He was especially interested in the semaphore—a "telegraphic" system used in Europe for the relaying of messages over great distances by means of bonfires or other similar devices. "The mails in our country are too slow," he observed to a group of friends. "This French telegraph is better, and would do even better in our clear atmosphere than here, where half the time the fogs obscure the sky." On another occasion, while discussing the semaphore, he said, "If we could only chain the lightning to carry our messages, *that* would be something!"

More and more, as he pondered upon the subject, he became convinced that the lightning, or *the electric spark,* could somehow be made to serve as a "mail carrier." And on the way home from Europe, he found a scientific corroboration of his idea. On shipboard he met Dr. Charles T. Jackson, a young Boston physician who spent much of his spare time in laboratory experiments. One day, as they were talking about electricity, Dr. Jackson remarked that an electric current could pass "instantaneously" through a wire stretching over a great many miles.

"In that case," said Morse, "I see no reason why human thought can not be instantaneously transmitted, by means of electricity, from any part of the world to any other part."

"I think you are right," replied Dr. Jackson. "All you'd need is an electric magnet to produce the sparks."

This, in substance, was the extent of their conversation. But in that brief conversation the telegraph was born.

V

AND THUS MORSE RETURNED to America and entered—somewhat against his will, perhaps—upon a new career. "I didn't abandon painting," he wrote years later. "Painting abandoned me." For the wheel of fortune had turned against him once more; his commissions and his savings had given out; and he found himself, almost at the half century mark of his life, a financial failure. And so he turned away from his art—temporarily, as he thought—and "drifted into the refuge of all American failures." He became an inventor.

Morse was equipped with several of the necessary assets for an inventor. He had patience, a vivid and daring imagination, a genius for drawing, a mechanical skill with his fingers, an insatiable curiosity to delve into the unknown, and a Yankee turn for the practical. And, in addition to his positive qualities, he possessed another, and negative, asset: he knew very little about mathematics. Abstract scientists make poor inventors. Their grasp upon the world is too nebulous for practical purposes. They dare not build a solid structure upon the shifting sands of their theories. Edison once remarked to a would-be inventor, "You are too much loaded up with trigonometry and calculus." From such loads, fortunately, Morse was comparatively free. Even his knowledge of electricity, at the outset, was scanty. He wasn't overburdened with the knowledge of what electricity *couldn't* do. He was more concerned with the possibility of what it *might* do. For Morse was a poet and not a scientist. His imagination was not limited by the barrier of formulas and figures. "I see no reason why human thought can not be instantaneously transmitted from any part of the world to any other part."

Two important discoveries had been made by others before

him. Electricity could be transmitted a great distance over wires. A bar of soft iron, surrounded by a coil of wire through which electricity had been passed, became a magnet which could be employed for a signaling device.

These ideas acted upon Morse like an electric current. It transformed the artist into an artisan, the poet into an inventor. The pay he received from his art students at New York University—he still taught painting as an avocation—was just about enough to buy the necessary apparatus for his early experiments. But it was not enough to supply him with sufficient food. In order to conceal his poverty, he brought his scanty groceries to his room at the University after dark. And he prepared his own meals.

And so he worked away at his invention, while the professors and the students shook their heads behind his back. Too bad for such a fine artist to be seized with this "miserable delusion!"

Illness, frustration, despondency—but never despair. "Just now I have more mental suffering . . . than ever before . . . My profession is that of a *beggar*, it exists on *charity* . . . Yet hope, in some shape or other, keeps on reviving me all the time."

Impelled by this hope, he shut himself up in his lodgings at the University, lined the walls with thousands of feet of copper wire, and went on with his long and patient explorations into the secret of electrical transmission. Much of the time he lived on a single meal a day, denied himself to his friends, refused to tell them of his privations, and consecrated himself to his telegraphy with the selfsame devotion that he had formerly given to his painting.

Occasionally, as the work progressed, he would usher a kindred spirit into his sanctum to show him the mystery of his "talking wires." One day he exhibited his mechanism to Robert G. Rankin, a lawyer with a scientific turn of mind. "You may not believe in it, Mr. Rankin, but at least you won't laugh at it like the rest of the world."

The gray-haired inventor was bustling about the room, explaining every part of the mechanism to his friend. "This is an electro-

magnetic telegraph. These coils, as you will observe, consist of an unbroken line of wire . . . The battery, with its positive and negative poles, is connected with a keyboard . . . Note the end of each lever on the keyboard. As you strike the lever against the disk to send a signal, the contact produces an electric impulse upon the wire leading out from the disk. A galvanic battery generates continuous current to an electro-magnet at a distant end of the wire. This electro-magnetic receiver actuates an armature to move a stylus into contact with a paper ribbon, impressing upon it dots and dashes that an operator can translate into the letters of the alphabet . . . Simple, isn't it? And so very practical."

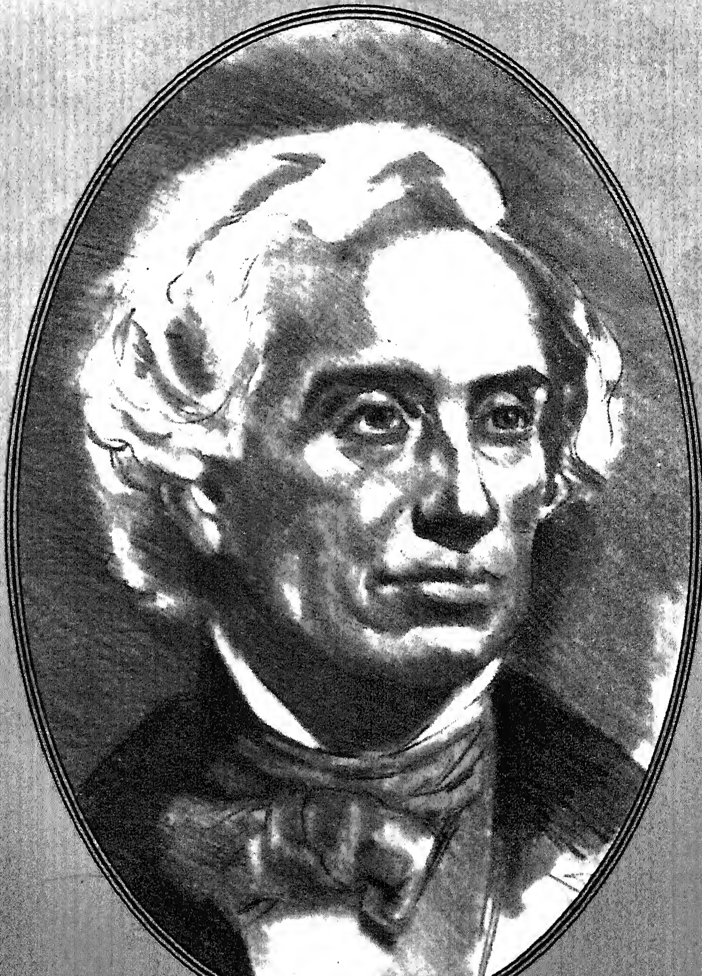
Carefully his friend examined the mechanism, and then fell silent for a while. Finally he spoke. "I'll be very frank with you, Professor. The thing is simple enough, yes. But practically, I am afraid it can serve only as a mantel-piece ornament."

And this, at the time, was the almost unanimous verdict of the world. When Morse applied for a patent in Washington, the director jestingly observed that it was high time for the Patent Office to be abolished—since "everything that possibly can be invented has already been invented."

Morse summarized his plight—every inventor's plight—in a letter to his friend, Catherine Pattison. "The condition of the inventor," he wrote, "is not enviable . . . If he has really made a *discovery,* which very word implies that it was before unknown to the world, he encounters the incredulity, the opposition, and even the sneers of many, who look upon him with a kind of pity, as a little beside himself if not quite mad." But if, on the other hand, he *fails* to make a discovery, "he subjects himself to the ridicule rather than the sympathy of his acquaintances, who will not be slow in attributing his failure to a want of that common sense in which, by implication, they so much abound, and which preserves them from the consequences of any such delusions."

And so the cowards disparaged his daring, and the foolish

Louis J. M. Daguerre



Samuel F. B. Morse

belittled his wit. But Morse went persistently on with his work. "Nothing but the consciousness that I have an invention . . . which is to contribute to the happiness of millions would have sustained me through so many and such lengthened trials of patience . . ."

But this was only the beginning of another struggle. He tried to sell his telegraph to the government, but met with the opposition of Congress. Year after year they debated the issue—and always with negative results. At times the situation looked favorable—"everyone here is convinced of the possibilities of my invention"—but always the opposition won out. For the majority of the members of Congress were blind to the scientific and the social implications of the telegraph. They met the inventor's arguments with sarcastic remarks. One of the representatives, Cave Johnson of Tennessee, facetiously suggested that if the government *must* throw away its money, it might set aside two funds—the first to endow mesmerism, and the second to encourage telegraphy. The chairman, Representative Winthrop of Massachusetts, retorted that it would take a scientific analysis to determine the "relative magnetic value" of mesmerism and telegraphy. And the members of the House bellowed their approval as Morse sat in the gallery and listened to all this buffoonery at his expense.

March 3, 1843. Congress is at the end of the session. A hundred and forty-eight bills are still awaiting their turn on the calendar. The chances are that Congress will never get around to the telegraph bill before the adjournment.

Throughout the day, Morse has been sitting in the gallery. It is late afternoon now, and his bill isn't anywhere near in sight.

Sunset, and the lamps are turned on. "I'm afraid it's all over, Professor. They'll never reach the bill before the closing hour."

Morse nods to his whispering friend. Another year of frustrated hope. And after this, still another year, and another . . .

He returns to his hotel. He figures out that he will have just

enough fare for his return to New York—and a balance of thirty-seven-and-a-half cents.

Nothing to do now, but to go to bed and to trust in God . . .

The next morning, as he went down to breakfast at his hotel, he found a visitor. Annie Ellsworth, the daughter of the Commissioner of Patents. "I have come to congratulate you, Professor."

"Congratulate me?"

"Yes, on the passage of your bill."

"I'm afraid you're mistaken, Miss Ellsworth. They never could have got around to it last night."

"But they did. My father was there when they passed it. And he saw the President sign it at midnight."

VI

MORSE WAS NOW able to rest from his labors. But only for a while, for the battle was not yet over. A number of other inventors began to dispute his claim to the patent. Some of them honestly thought themselves to be in the right. It is a peculiar characteristic of the human race that new ideas lodge themselves simultaneously in many minds. In the final analysis, the telegraph—like so many other inventions—was a social rather than an individual discovery. In the scientific knowledge of the day, many minds were prepared for the germ of the telegraphic idea to take root. Morse was not alone in his claim to the discovery of the telegraph. Other men, like Dr. Jackson, Professor Henry, Professor Wheatstone and Dr. Steinheil, made a vigorous attempt to get the credit for the invention. And Morse just as vigorously opposed them. And the blows that he struck at his opponents—it must be confessed—were not always fair. For Morse was a man of decided views and a fighting heart. And he believed that all's fair in law and war. He therefore fought, with every means in his power, to establish himself as the sole discoverer of the principle of telegraphy.

In this fight he was partially, but not wholly, successful. After considerable litigation, the Supreme Court decided that while Morse was not the only man who had *invented the telegraph,* he was the first man who had *perfected and patented the instrument as adopted by the United States.*

And thus he was finally freed from the financial worries that had dogged his footsteps for over fifty years. He could now indulge in the luxury of a second marriage. And grumble at the honors which might have stimulated him in the hunger of his youth, but which only bored him in the indifference of his old age. "Strange how the best things in life come to us when the keen edge of our enjoyment is blunted." The ovations and the medals and the titles and the crosses that he received, both at home and abroad, were but a hazy background to the five bright days of his life: the first, in 1835, when he demonstrated to his friends the practicability of the telegraph; the second, in 1840, when he received his patent; the third, in 1843, when the government purchased his telegraph; the fourth, in 1844, when the first telegram in American history was flashed over the wires from Baltimore to Washington; and the fifth, in 1866, when England wired a greeting to America over the newly laid transatlantic cable. These five days in the life of Samuel Morse marked the beginning of a new age—an era of quicker communication and, as he hoped, of friendlier understanding between individuals and cities and nations.

VII

Seventy-five years old now. The serenity of the sunset over clearing skies. His fighting days were over. He chuckled when reminded of his earlier battles. How persistently he had demanded his pound of flesh! That time, for example, when the Scotch inventor, Alexander Bain, had fought for recognition as the co-discoverer of some of the principles of telegraphy. Morse had

insisted that he alone had been responsible for the entire invention. When Bain was planning a trip to America, together with his family, in order to press his claim, a newspaper reporter had advised him to leave his children at home. "If you bring them to America," said the reporter, "Mr. Morse will claim them as his own exclusive inventions."

Well, he could afford to be tolerant now, and contented, and calm. But not idle. His unspent energy still demanded its daily quota of labor. Busy from morning to night, often to midnight, collecting the material for a history of the telegraph. He laughed away his wife's warnings to "take it easy for a spell." He told her that it was "better to wear out than to rust out."

And now, eighty-one years young. His two brothers had passed on. "Today, more than ever, I feel stirred to diligent improvement." Always a devout churchman, he now read the Bible continually. "I love to be studying the Guide-Book of the country for which I am about to sail."

And on the final day, when the doctor tapped his chest for the telltale sound of pneumonia—"this is how we doctors telegraph" —the patient smiled in his pain. "The best is yet to come."

ELIAS HOWE

Important Dates in the Life of Elias Howe

1819—Born, Spencer, Mass.

1835—Entered factory of a manufacturer of cotton machinery to learn the machinist's trade.

1845—Completed the model of a sewing machine.

1846—Took out patent for sewing machine.

1847—Entered employment of a corset manufacturer to whom he sold the English rights to the sewing machine.

1849—Returned to Boston financially impoverished.

1854—Established rights to sewing machine after prolonged battle in the courts.

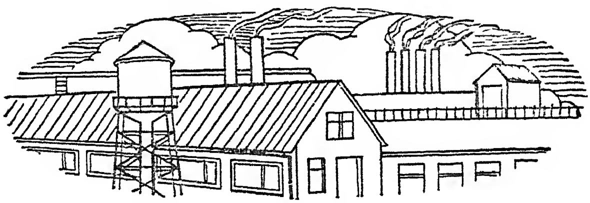
1861—Patent for sewing machine extended.

1865—Organized the Howe Machine Company in Bridgeport, Conn.

1867—Died, Brooklyn, N.Y.

Elias Howe

1819–1867



WHEN HOWE invented the sewing machine, he had no desire to save womankind. He merely wanted to rescue one kind woman —his wife. He couldn't bear to see her coughing away her strength as she sat devotedly plying her needle until late into the night. No end to the mending of the sheets and the blankets and the sewing of the clothes for the family. "If only I could do something to make her life easier!" Stitch by slow stitch, seam after protracted seam—and with every prick of the needle, her lips grew paler and her eyes more feverish. "She must take better care of herself," warned the doctor, "or she may go into a consumption."

And so the necessity for his wife's comfort was the mother of Howe's invention. More money for the family needs, less labor for his wife.

But her labor was ended long before he was able to make any money on his invention. She died an early victim of tuberculosis.

II

Howe's early training as a mechanic, like that of the Greek god, Hephaestus, was due to a physical defect. He was born lame. A sickly child, not much good for the strenuous work in the fields. His father, Elias Howe, Senior, had a saw-mill and a machine shop, as well as a farm, at Spencer—a village about twenty miles from Worcester, Massachusetts. While the seven other children helped him with the heavier chores, he allowed the "lazy little tyke"—the youngest of the lot—to roam around and to dream. And, occasionally, to lend a hand in the lighter tasks of the household and the mill.

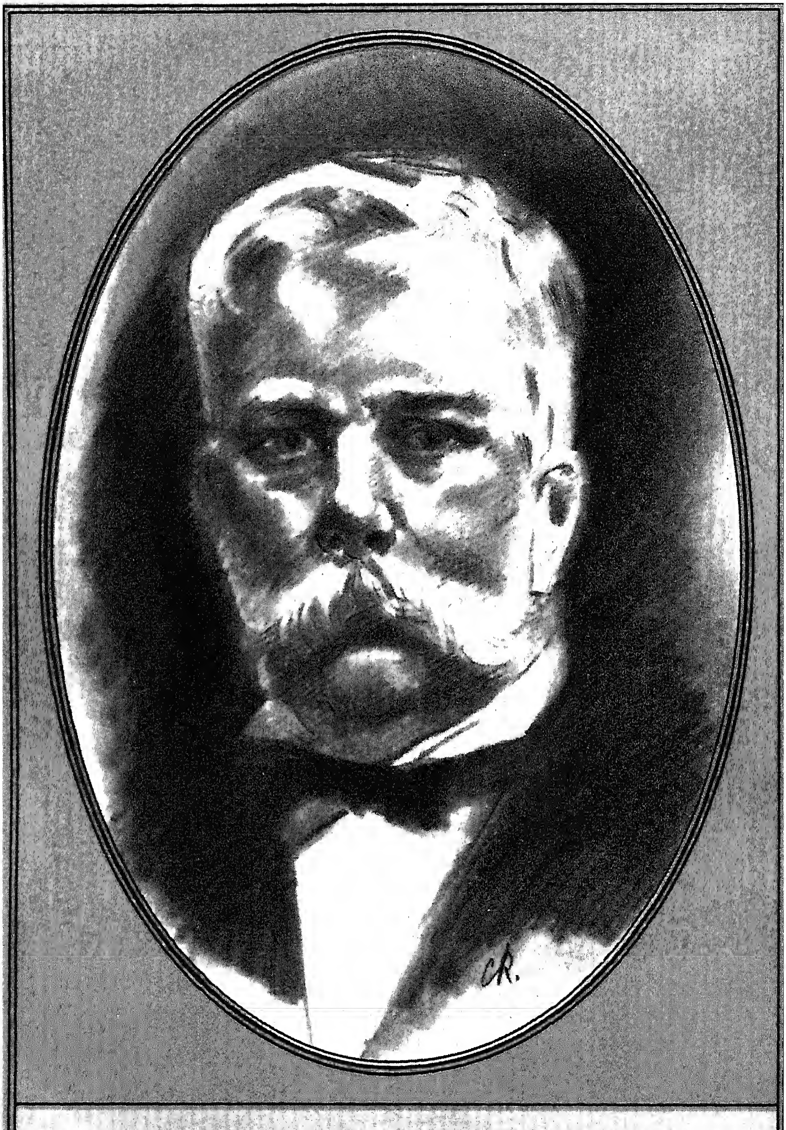
And thus, young Elias became early acquainted with the wheels that moved the world. The mechanical saws that cut through a heavy log as easily as a knife cuts through a piece of butter. The ratchet-wheels with the pointed teeth that stuck out all around the edge. The pawls that caught at the ratchet-teeth like a man's fingers and kept the wheels moving in only one direction. The spinning machines that combed the cotton into threads and the looms that wove the threads into fabrics. The levers that lifted things, and the lathes that rounded them into beautiful shapes. The thousand and one different kinds of work done by machinery. And so much faster and better than by the human hand!

"I wonder who makes all these machines?" he once asked his father.

"Inventors. Men like your uncles, but much cleverer, I imagine."

So that's what you called them. Inventors. His two uncles made all sorts of clever little tools, but nothing like these wonderful machines. He, too, could already tinker around with "silly little ideas" for new kinds of tools and make repairs on old ones. Knew how to "true" a grindstone, glaze a window, solder a tea-

Elias Howe



George Westinghouse

kettle, shingle a roof, build a corn-crib, and put together the wheels of a machine that had fallen apart. "Clever fingers," said the neighbors, "but not much taste for farming."

Or for schooling. Attended school only in the winter. And his entire education in the three R's, when added up, amounted to something less than two years.

And then, at sixteen, his formal education was at an end. "No shoulders for the plough, no brains for books." But eyes and hands for precision in the shaping of designs. "Elias should turn into a pretty good mechanic," said his father, and sent him to Lowell for his apprenticeship.

Considerable work in the making and the repairing of cotton looms. And considerable experience in the making of friends. A sunny disposition, full of laughter, kindnesses and pranks.

For two years he worked and jested and sang through his apprenticeship, and then he found himself without employment. The panic of 1837, and the shutting down of the factories and the mills. The crippled young mechanic hobbled his way from town to town until he finally found work in Boston. A quaint master, a congenial job, and plenty of miscellaneous work to feed his imagination and to test his skill.

He was not yet out of his teens at the time.

III

HIS EMPLOYER, Ari Davis, was an amateur philosopher, would-be actor, and professional mechanic of extraordinary ability. He repaired, among other things, the scientific instruments for the Harvard faculty; and these learned gentlemen often came to him "to clean not only the rust out of our engines but the cobwebs out of our brains."

An "odd duck"—this metaphysical mechanic—"you'd never guess, to look at his queer head, that it held so many ideas." And these ideas, like the impartial rays of the sun, were equally

free to all who came to seek them. He started many a worker on the way to some profitable business enterprise or mechanical device. Though he never invented anything himself—"pains too great, profits too small"—he was a veritable treasure-house of inventive suggestions. A Yankee Socrates of the hammer and forge. "To sit at the bench under your watchful eye," as one of the Harvard professors remarked, "is better than any college education in the technical arts."

And so it proved in the case of Elias Howe. One day, as he was engaged in his work, he overheard a casual conversation between Mr. Davis and a customer.

"I have thought," said the customer, "to invent a knitting machine."

"Why not, rather, a sewing machine?" suggested Davis.

"Impossible. Couldn't get a needle to stitch downward through the cloth and then to reverse itself and stitch upward again."

"Not so impossible as you think," retorted Davis. "Could do it myself if I had the time. Sort of contraption of two needles—one above and one underneath the cloth."

Contraption of two needles. Howe was struck with the idea, though he made no sign that he was listening. Would be nice to try it out some day. But not just yet. Too busy with his regular work. So tired at night, he'd often go to bed without his supper.

And so he dropped the idea for the present. Instead, he undertook another kind of job. Marriage—and the bringing up of a family. A sickly wife, three hungry children, and nine dollars a week to take care of them all.

Occasionally his wife made clothes for the neighbors to bring in an extra penny. A clever seamstress—but oh, so delicate! It was while watching her at her needlework that he recalled the conversation at Ari Davis' shop.

A sewing machine. To lessen the burdens of handwork. Two needles instead of one. Yes, he would try it! Now, while he was still young. Let his wife enjoy her comfort before it was too late—

and his children, the education that he couldn't afford for himself.

He gave up his job, and gambled everything on the uncertainty of an invention that had a thousand chances for failure to a single chance for success.

And—the irony of a fanatical devotion to an idea—in order to save his wife from drudgery in the future, he saddled upon her for the present a greater drudgery than ever before. He got her to support the family with her needlework, while he experimented with the "impossible phantasy" of a sewing machine.

"A shiftless, good-for-nothing loafer," grumbled the neighbors. "A brave and brilliant genius," declared his wife. "And some day the world will recognize you for what you are."

IV

When he began to experiment with the idea of a sewing machine (in 1843), Howe was utterly unacquainted with the work that had already been accomplished in the field. For he was a mechanic and not a scholar. And so he took no trouble to read the literature on the subject. He didn't know, for example, that in 1790 Thomas Saint had invented a stitching machine in England; or that in 1830 Barthelemi Thimmonier had patented a sewing machine in France; or that in 1834 Walter Hunt had built, but had neglected to patent, a sewing machine in America. Nor did he know that the tailors and the seamstresses of Paris, afraid that the competition of this "diabolical sewing engine" would throw them out of work, had mobbed Thimmonier's workshop and wrecked eighty of his machines. Had he familiarized himself with the principles of these earlier inventions, Howe might have saved himself considerable time and trouble in the gropings of his preliminary experiments. But, on the other hand, had he learned about the failures of the inventions bestowed upon a public that was not as yet ready to accept them, he might have given up the idea altogether. And so it was perhaps for the best that Howe

entered upon his experiments unaware either of the ideas or the disappointments of his predecessors.

And his experiments began with the principle of the two needles. But what sort of needles? And how to combine them so as to make a continuous stitch? These were the two problems he must solve before he could go ahead with his model.

And finally the solution came to him. Above the cloth, a needle with the eye *at the point.* And underneath the cloth, a needle to serve *as a shuttle.* A simple device, once you hit upon the idea of the point-eyed needle. For this needle, as it pierces through the cloth, carries to the underside an open loop of thread. And then the shuttle-like needle, as it moves back and forth underneath the cloth, interweaves its own thread into the open loop. And thus the two threads are combined into a lock-stitch, after the manner of a shuttle and a loom.

Howe's sewing machine, therefore, was in reality a modification of the weaving machine—a mechanism of weaving needles.

His first model was completed when he was only twenty-six. A long life was still ahead of him, he thought. A life full of all the rich blessings of success. Relaxation for himself—how he did hate work! Education for his children. And for his wife, good food and fresh air, and medicine, and plenty of rest.

But Elias Howe was an inventor, not a man of the world. In the exuberance of his youthful genius, he had no idea that the world often repaid services with stones.

He took out a patent—no difficulty about that—and was ready to exhibit the wonders of the sewing machine to the public. Two hundred and fifty stitches in one minute! Amazing toy! But of what practical use? "It would only throw thousands out of work . . . precipitate a panic . . . revolutionize our traditional way of life . . . Better stick to our old-fashioned methods and our old-fashioned prosperity . . ."

And so, everybody admired his machine and nobody bought

it. A man with plenty of honor, but with no honorarium, in his own country.

But perhaps another country might treat him better. Why not try to sell his patent in England? A country of manufacturers. The English might have a better understanding of the commercial value of his sewing machine.

Accordingly he decided to send his brother Amasa, with a model of his sewing machine, to London. In order to raise the money for the trip, he got a job as a locomotive engineer on the Boston and Albany Railroad.

His brother, almost as good a mechanic as Elias, was almost as poor a business man. He sold the model, along with all the British manufacturing rights, for $1250. And, to top it all, he virtually sold Elias into slavery. The crafty purchaser of the British rights, a corset maker by the name of William Thomas, demanded—as a part of the bargain—the fulltime services of the inventor. At $15 a week.

Hopefully Elias and his wife and their three children embarked —in the steerage—for England. New scenes, new blows.

V

THEY MOVED into an attic room in a London slum, and Elias set himself to the building of sewing machines for his "master" at his starvation wage. "And see to it that you don't loaf on your job. Can't afford to support loafers, you know." When he got to bed at night, Howe was frequently so exhausted that "I wished the morning would never come, so I could sleep and sleep and sleep . . ."

Eight months of this slavery, and then he rebelled. He quarreled with his "pinchpenny" employer, and threw up his job. And it took the last farthing he had saved to send his family back to America.

As for himself, he would try his luck in England for a little

while longer. He borrowed money from a coachman whose friendship he had made—he had a genius for making friends—and set himself to the task of improving his machine.

But his borrowed money soon gave out—and along with it, his last vestige of hope for any further prospects in England. Back to America. But how? By this time he didn't have the fare even for the steerage. There was only one avenue of escape—and this was so narrow that he just barely managed to squeeze through. He pawned his patent papers—"just enough to feed my bundle of skin and bones for the present"—and waited for an opportunity to work his way across in a ship's galley.

Fortunately the opportunity came before his food gave out. When the ship was ready to sail, he couldn't afford a cab for his luggage. And so he bundled his belongings into a handcart and pushed his way limpingly to the wharf.

VI

Back to New York, and a job in a machine shop. To earn enough money for the return of his furniture from England and for his own return to his family in Boston.

And, as usual, further tragedy ahead. Stranger than any fiction, this dramatic story of his life. He sent for his furniture—and the ship, with everything aboard, was wrecked in a tempest off Cape Cod. "Oh, well, at least I have my family left." Soon, very soon, he would be with them again.

Sooner than he expected. He received word that his wife was very ill. Had suffered a hemorrhage. "Hurry, or it may be too late!"

He arrived just in time to hold her in his arms as she died.

VII

The low ebb of his happiness and his hopes. And then, the tide began to turn.

And—another unexpected twist in the plot of his drama—Howe received his final justice as the result of a series of injustices. He became rich because a number of people infringed upon his patent. Unable to capitalize his own genius, he made a fortune when others tried to capitalize it against him.

It all started as follows: He was making a few sewing machines in a little factory of his own in New York—living from hand to mouth and, for lack of financial ammunition, hiding his talents under a bushel—when he was startled one day by a flaming advertisement in front of a tailor establishment on Fifth Avenue.

A Great
CURIOSITY!!
The
YANKEE SEWING MACHINE
is now
EXHIBITING
AT THIS PLACE
from
8 A.M. to 5 P.M.
This Amazing Machine can make a Pair of
Pantaloons in 40 Minutes!!!

Howe entered the building. Amazing machine, indeed. His own sewing machine, with but a few minor modifications, paraded as the invention of another man. Isaac M. Singer. Howe began to make inquiries about the "pirate" of his brain child. A remarkable personality, this Singer. Started as an odd job journeyman and amateur inventor, but discovered that he had greater talents as an "improver and promoter" of the inventions of other people. One day, while examining a Howe machine that had been brought to him for repair, he had decided to build a "better machine" of his own and to market it on a "grandiose" scale. All of Singer's ideas, like his own imposing person, were

grandiose. He lost no time in constructing his "superior" machine, taking out a patent, and exploiting his "invention" to the public in a fanfare of bombastic display.

And the people came, and saw, and were conquered. While Howe managed, with the greatest difficulty, to sell only fourteen of his own machines, Singer was selling his by the hundreds and the thousands.

And, in addition to the Singer machine, other sewing machines were being sold everywhere in violation of Howe's patent. This final culmination of insults added to the accumulation of his injuries was just the spur that he needed to drive him into action. He decided to fight for his rights.

At this critical juncture, two of his friends came to the rescue. The first was Anson Burlingame, a Cambridge attorney who was about to sail for England on private business. He offered to redeem Howe's patent papers which were still being held at the London pawnshop. The second volunteer was George W. Bliss who, in return for a share in the business, undertook to defray the expenses of the lawsuits against the infringers of the patents.

Two years of legal battles, and Howe won several of his cases against the minor transgressors. And now remained his major fight against Singer, the most dangerous rival of them all.

This fight dragged on for three years. Singer's lawyers were as cunning as their client. In order to protract the battle until Singer's business had become safely established, they insisted upon the clarification of two important issues.

In the first place, they tried to prove that Singer's machine was—in several essential features—superior to Howe's machine. This claim they were easily able to substantiate. Singer's machine *was* superior. For Singer had added, among other improvements, a treadle which enabled the operator to work the machine by foot and thus left his hands free for holding the cloth; a continuous wheel feed which caused the machine to operate with an even, progressive movement; and a yielding vertical foot presser

which held the cloth firmly on the table as the stitches were being made. Three distinct advances over Howe's original idea.

But, in the second place, Singer's lawyers tried to prove that the sewing machine was not Howe's idea at all. They dug up, from the rubbish in an old workshop, a dismantled model of the machine that Walter Hunt had made in 1834. But this machine had not been patented. Morever, when put together, it failed to work. In several ways this model had anticipated Howe's idea—but only in an embryonic fashion. It had never come to life. Howe was the first American to make and to patent a workable sewing machine.

And such was the final verdict of the courts. Howe's invention was invalidated neither by the unsuccessful model of Walter Hunt nor by the successful modifications of Isaac M. Singer. In February, 1854, Judge Sprague of Massachusetts handed down the following decision which was to establish a precedent for all future patent litigation:

1. "There is no evidence in this case that leaves a shadow of doubt, that, for the benefit conferred upon the public by the introduction of a sewing machine, the public are indebted to Mr. Howe.

2. "A machine, in order to anticipate any subsequent discovery, must be perfected—that is, made so as to be of practical utility, and not merely experimental and ending in experiment. Until of practical utility, the public attention is not called to the invention; it does not give to the public that which the public lays hold of as beneficial."

And thus Howe was vindicated at last. He received from Singer a sum of $15,000 for past royalties.

But this was only the beginning of his prosperity. In a flash of inspiration during one of the court sessions, a lawyer for the defense had offered a practical suggestion for all those involved in the trial. "At this court today are assembled the men who control the sewing machine manufacture of the Globe. Let them join

hands instead of shutting their fists, and they will find vastly more profit in peace than in war."

The birth of the monopoly idea. Advised by his friends, Howe accepted this idea. And so, instead of taking out an injunction against the infringers of his patent, he made an agreement with them—twenty-four companies in all—to go on with the manufacturing of his machine and to pay him a royalty of $4 on every machine sold.

Well on the road now to tremendous fortune on the wings of his fame.

VIII

HE THOUGHT of his past dreams, of his many disappointments and tragedies, and of the strange interweavings of Destiny's web—his triumph in lessening the burdens of millions of women in the world, and his failure to save the life of the one woman he had loved. He recalled how, at his wife's death, he had been obliged to borrow from his brother-in-law a suit of clothes for the funeral. And now he had enough money to supply a whole regiment with clothes. And with other equipment, too.

To supply a regiment—not a bad idea. The Civil War, 1861. Owing to his lameness, he would have been exempted from the draft. But he volunteered his services, organized the Seventeenth Connecticut Regiment, and equipped the soldiers with uniforms and every one of the officers with a horse.

They appointed him colonel. But he turned down the honor. He enlisted as a private. On one occasion, when the regimental pay was overdue, he gave the paymaster $31,000 "so that the soldiers may suffer no undue hardships in addition to their other troubles and dangers."

And now the war was over. Peace at last—not only to the nation but to Elias Howe. Sit back and enjoy the fruits of your labor. Untold riches—royalties amounting, for months at a

stretch, to $4,000 a day! A well-earned reward for your patience, your perseverance, and your hope. The expectation of a serene and painless holiday in the twilight of your life.

But—the irony of his fate again. An attack of Bright's disease—hopeless complications—and an all-too-early death at forty-eight. "When the time comes for us to live, it is time to die."

GEORGE WESTINGHOUSE

Important Dates in the Life of George Westinghouse

1846—Born, Central Bridge, New York.

1863–65—Served in the Union army and navy.

1869—Patented the air brake. Organized the Westinghouse Air Brake Company.

1872—Devised the automatic air brake.

1884—Launched company to distribute gas throughout Pittsburgh and outlying communities.

1886—Illuminated Buffalo. It became the first city in the United States to receive alternating current.

1893—Secured contract to supply electricity for the Chicago Exposition.

1894—Installed first dynamo to harness the electric power of Niagara Falls.

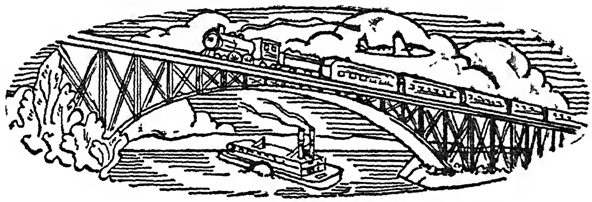
1905—Demonstrated the electrified locomotive.

1910—Invented air springs for automobiles.

1914—Died, New York City.

George Westinghouse

1846–1914



GEORGE WESTINGHOUSE was not merely a successful inventor; he was a successful American. Starting life in the humblest circumstances, without capital, without connections, without substantial schooling, he succeeded in turning several ideas into working realities—and these ideas were what the whole world was waiting for.

The Westinghouse family was of Saxon stock—Westinghausen was originally the name. One branch emigrated to England and eventually to America. This was the line that produced the inventor.

His father was a mechanic who manufactured agricultural machinery. His business was at first located in the village of Central Bridge, in upper New York. But he moved to Schenectady, a larger industrial center. And here George, one of his five sons, grew to manhood.

From the first George was unmanageable. He played hooky from the classroom. He stretched out on the grass whittling wood into odd models of machines. When his father disciplined him, he flew into a fury. His behavior was entirely unpredictable.

When George was fourteen his father made a bargain to pay him for every hour he worked in his machine shop after school. George agreed. One Saturday before leaving on a business trip, his father directed him to level a pile of pipes. George's friends came around and invited him to go for a swim and a picnic. The lad couldn't resist the temptation, and he put his brains to work for him instead of his hands. He rigged up a mechanism which, harnessed to a power machine, fed the pipes and cut them automatically. Then, persuading one of his father's foremen to keep an eye on the machine, he took a holiday at the swimming hole. When his father returned expecting George to be deeply involved in manual labor, he was shown the completed pile of pipes. They had been cut in record time. No other workmen in the shop could have equalled George's ingenuity or his audacity.

Yet despite his cleverness in matters close to heart, George was a sluggish student. And he wasn't the least concerned about his inability to express himself readily in verbs and nouns and ringing phrases. He was content to tinker with gadgets.

He failed to satisfy the requirements of his father. He was bored with the routine job of turning out the "cut and dry" machinery required in the business. He spent all his spare hours using the tools of the shop to fashion gadgets that had no practical use. They were wasteful toys, the dreams of an idle mind. They were "trash" and Westinghouse Senior threw them into the junk pile. He couldn't for the life of him fathom "what made George's mind tick."

In view of his son's lack of interest in his machine shop, he decided to give him the chance to follow a profession. He sent the lad to Union College. But George's performance in the halls of learning was less than mediocre. His professors labeled him as their one student least likely to succeed. He was so inept in the curriculum—languages and literature—that the College president called in the senior Westinghouse and told him it was a waste of money for his son "to pursue studies in which he has no heart."

And so George went back to the machine shop and, so far as anyone could judge, to a life of obscurity. No successful man ever showed less promise of "getting ahead" than George Westinghouse. But the truth is there are men like him in all ages. Unable and unwilling to fit into the accepted jobs of society, they proceed to invent new ones. Westinghouse was such a person. Seeking employment for himself, he remade the world.

II

FROM HIS EARLIEST Westinghouse never bothered to adapt himself to other people's schemes of learning or earning. He continually speculated upon ways of improving upon them. He was not interested in doing well what had been done before. He was concerned with doing better what had never been done. His mind always seemed to be shooting off in a tangent from the orbit of other people's rationale. However, from its position of tangent, it gained the necessary perspective with which to foresee and oversee.

A demonstration of George's ability to find the obvious solution for a situation that baffled conventional minds occurred not long after he had returned from college to his father's shop. During a business trip to Albany, his train was suddenly halted by an accident on the track ahead. Two cars had become derailed. Westinghouse and the other passengers were delayed for several hours while the wrecking crew laboriously pried the cars bit by bit and hoisted them upon the track again.

"Whew, what a tiresome wait!" a fellow traveler remarked to Westinghouse as they watched the proceedings. "But it can't be helped."

"Yes, it *can* be helped," replied Westinghouse. "The whole job could have been accomplished in a quarter of an hour if they had only clamped side rails at an angle to the main track and extended them to the derailed cars. They could have hitched an engine

to the cars and pulled them back onto the track with practically no effort. As a matter of fact, all railroads should have car replacers on hand for accidents like this!"

"Why don't you sell the idea to them?" rejoined the other caustically.

"I think I will," replied Westinghouse with quiet determination.

Before he went to bed that night he had worked out the plans for car replacers. But when he showed them to his father, the older man, thoroughly fed up with his son's "worthless devices," replied critically, "Stay with the business you were trained for, George. What in blazes do you know about railroads?"

Despite his father's dissuasion, George approached several businessmen in the community with his proposition, and he actually persuaded two of them to invest a modest sum of money in a company to manufacture the replacer.

And so Westinghouse was launched upon his career.

Early in this career he experienced the crookedness of his business partners. They hatched a conspiracy to deprive him of his patents and seize control of the firm. Westinghouse walked out contemptuously, abandoning the company to them, but he fought successfully to retain his patents. And he arranged a deal with the steel-casting firm of Alexander Woods, offering it the rights to his inventions in return for employment as a salesman.

And, indeed, he had a world to sell. For just before his quarrel with his partners, he had invented a mechanism that was to revolutionize transportation. Just as his scheme for rerailing cars had occurred to him as the result of a train accident, so, too, this new and vastly more important invention had its origin in a railroad wreck.

One day while Westinghouse traveled to Troy, New York, on business, his train stopped suddenly and he was jolted from his seat. The engineer had been forced to a halt coming upon a wreck a brief distance ahead. Two freight trains had collided.

George dismounted to view the shambles. Thousands of dollars

worth of merchandise was scattered to the winds. A rescue party was rendering Herculean efforts to extricate a brakeman caught beneath the debris. George inquired of a bystander how the accident had happened. The visibility was excellent. The road was straight without a curve or obstruction. What had been the reason for the mishap?

"The first freight train ran smack into the rear of the second," explained the bystander. "The engineer saw the freighter ahead of him. But he didn't have enough time to stop. You know one simply can't halt a heavy freight train in a matter of seconds!"

One couldn't stop a heavy freight train in a matter of seconds. That was the essence of the problem. The whole development of the railroads had been hampered by the lack of an effective brake which would halt trains swiftly and securely and avert scores of accidents. The brake system in use on trains in 1865 was terribly clumsy. The engineer gave the signal to a crew of brakemen who rushed along the tops of the separate cars desperately tightening brake wheels with pick handles. Each handwheel was connected to a chain beneath the train which, when tightened, clamped a pair of brakes upon a set of wheels. Usually the brakemen had to commence turning the handwheels half a mile before reaching a station in order to bring the train to a stop.

The entire future of the railroads was clouded by the lack of a decent brake. And George Westinghouse set about to invent one.

III

A LUCKY INCIDENT brought him ultimate success, but the invention was seeded in months of hard thinking. The ideal system for braking would enable the engineer to apply the brakes himself by means of some device close at hand. But how would this mechanism be run? At first Westinghouse turned to steam. Suppose the brakes on each car were joined to the coupling which connected the cars and the whole system was controlled by the

engineer from his locomotive simply by applying steam pressure?

Westinghouse devised a model of such a mechanism. But he soon discovered that a steam cylinder which was powerful enough to generate sufficient pressure to operate a chain of brakes the length of the train would have to be larger than the locomotive itself.

He next experimented with the idea of dividing the system into separate cylinders for each car, each to be fed with steam from the engine. But this was impractical also. For the steam was subject to changes in the weather. In the summer it would condense before it reached the final car. In the winter it would freeze. But if steam were impractical, what other agent of power could possibly be employed? Westinghouse had reached the limit of his ingenuity; but chance suddenly beamed upon him.

One hot summer day as he sat engrossed in the problem, a young woman entered his shop and delivered a sales talk. She tried to sell him a subscription to a magazine, *The Living Age*. Westinghouse had little time for reading magazines, and he was rather abrupt with her. However, she succeeded in mollifying him. He yielded finally and took a subscription. This altered his career.

While glancing over his first issue of *The Living Age,* Westinghouse's attention was attracted to an article which set his pulse tingling. The article described the difficulties that had confronted a group of engineers engaged in digging a seven-mile tunnel through the Alps at Mont Cenis on the French-Italian border. They had discovered that it would take two crews of workmen cutting manually through the mountain from opposite ends almost fifty years to meet in the middle! Furthermore it was impossible to introduce machinery run by steam, for scarcely enough air reached the underground to keep the workmen alive, let alone to nourish the fires that produced steam for the machinery.

Suddenly, however, one of the engineers was struck with an idea. An Englishman had just invented an apparatus which drilled through solid rock like a battering ram. This machine was

operated by steam. However, the Mont Cenis engineer was acquainted with another fact. Recently, several Italian mechanics had driven a train up a steep slope of the Apennines with a motor run by compressed air. These two occurrences taking place in different areas of the world gave the engineer his inspiration. It occurred to him that if features of the Englishman's machine were combined with those of the Italian's motor, a mechanism could perhaps be designed that would be adequate to the task of tunneling through Mont Cenis.

Acting on this hunch he devised such a machine. And it proved to be a success. The problem of digging through Mont Cenis expeditiously had been solved, concluded the article, "by a perforating mechanism, moved by simple air, compressed to one sixth of its natural bulk, and exercising, when set free, an expansive force equal to six atmospheres!"

Upon finishing the article, George Westinghouse sprang from his chair. This was the solution to his own problem. This was the power he had been seeking for his brake. Compressed air! If air, sent through thousands of feet of pipe, possessed enough power to drive a drill through the rock of a mountain, it could certainly be carried the length of a train and yet maintain enough pressure to clamp brakes upon the very last pair of wheels.

He had found the answer.

IV

THE EARLY ATTEMPTS by the inventor to gain a hearing for his invention followed a typical pattern. Although civilization was waiting for the air brake, few were keen enough to recognize its value when Westinghouse tried to sell it commercially.

The more Westinghouse pleaded with the magnates of the railroad industry, the more they shook their heads angrily at the notion that air could successfully brake a train when the most carefully-calculated devices of the foremost engineers had failed

to do the trick. Even Westinghouse's friends began to call him "crazy George." The most charitable of them nodded their heads in pity.

Finally, however, opportunity knocked at the door. An important official of the Steubenville Division of the Panhandle Railway, Superintendent W. W. Card, more keen-sighted than his colleagues, met the young inventor and came away impressed with the potentialities of his invention. He persuaded his board of directors to allow Westinghouse to equip one of their trains with his air brake for a demonstration.

It was decided to hold the trial run along a stretch of road between Pittsburgh and Steubenville. On the day of the test the Panhandle officials climbed aboard the express. And Westinghouse joined them for the most important ride of his life.

Not being scheduled to test the brakes for several miles, the engineer opened his throttle and settled down peacefully to an enjoyable run. His complacency was nipped in the bud. When he emerged from a tunnel just several hundred yards from the start, at a speed of thirty miles an hour, he saw something that froze his blood. A cartman, not heeding his signal, had driven onto the tracks. Whipping his horses to clear the rails before the train arrived, he goaded one of them into rearing. It threw him from his seat. He screamed as the locomotive plunged towards him. The engineer applied the brake with every ounce of energy he possessed. The train jolted to a stop four feet from the paralyzed cartman.

The railroad officials, thrown from their seats, strode up to the locomotive to demand an explanation. They rubbed bruised knees and aching elbows. But their anger quickly disappeared when they learned what had happened and understood its significance for their industry. Westinghouse's air brake was a resounding success!

Three months after this spine-chilling ride, a group of Pittsburgh railroad magnates met with the inventor to organize the

Westinghouse Air Brake Company. And the young inventor was unanimously named president.

He had reached the height of success at the age of twenty-four.

V

WESTINGHOUSE'S air brake dynamized a tremendous expansion of the railways. And Westinghouse himself became world-celebrated. Orders for his brakes came from every country in Europe and Asia as well as the United States. They are standard equipment in trains today. Initially his brake performed efficiently for passenger trains only. And to meet the demand for a mechanism that would halt huge freight trains with equal effect, he devised an automatic air brake based essentially on the same principles as his original device. It was able to stop a fifty-car freighter traveling at a moderate speed in two seconds!

In addition, Westinghouse completely overhauled the signal system of the railroads. He developed a friction draft gear which controlled the speed of the cars; he devised a method of absorbing the blow of one car upon another when the train stopped or started. He developed automatic signals which contributed greatly to the safety of rail transportation.

At the heyday of his fortune, he refused to rest from his work. "Work is my vacation." Not satisfied with having reformed the railroads, he turned his gifts to other industries with equally startling results.

On the occasion of his wife's birthday—he had met Marguerite Erskine Walker on a train and married her after a whirlwind courtship—Westinghouse bought an impressive three-story mansion in Pittsburgh which he christened *Solitude*. Thoroughly studying the land upon which *Solitude* stood, he came to the conclusion that natural gas might be found on it. With his usual far-sightedness he believed the day had come when natural gas, employed as a low cost fuel, could be piped into every home and industrial establishment in Pittsburgh.

He directed his engineers to dig. Good-naturedly he accepted the ridicule of his friends. But he had the final laugh. Once again one of "crazy George's" hunches proved true. When the workmen reached a depth of almost sixteen hundred feet, they struck natural gas. To the consternation of his wife and neighbors, it spouted upward like a geyser, bespattering the spacious lawns of *Solitude*. But Westinghouse grinned happily.

Natural gas was a spontaneous and frequently uncontrollable phenomenon. Before Westinghouse could make it available as a citywide fuel, he had to eliminate the danger of sudden explosions which could bring about the loss of lives and property. With typical resourcefulness he devised a mechanism consisting of interlocking pipes of different capacities. The gas, as it passed through these pipes, expanded by different stages so that when it reached the point of delivery it was readily controllable.

Westinghouse organized the transportation of gas into a business. The Philadelphia Company, as it was called, grew into a tremendous utility, supplying subsequently not only gas but electric power and streetcar transportation for all of Pittsburgh and outlying communities. Its service to the city far outweighed its profits. For as Westinghouse had foreseen, iron and steel companies, attracted by the prospect of cheap fuel, moved into Pittsburgh and transformed the city into the mammoth manufacturing center that it is today.

VI

HAVING SUCCESSFULLY HARNESSED natural gas, the irrepressible Westinghouse now turned to a new form of power—electricity. Witnessing in 1880 a demonstration of Edison's recently-devised incandescent lamp, he discovered that the distance over which electricity could be transmitted from the generator by means of the Edison system was strictly limited to several miles. Furthermore, it could be sent only at low voltages.

Westinghouse was convinced that another method of conveying electricity had to be discovered if the new power were not to be restricted to small, experimental areas. He searched for a way to transmit electricity at high pressure, (for only in this fashion could it be sent over long distances); but at the same time to step down the pressure wherever necessary. In a sense the problem of transforming electricity from high voltages at its origin to low pressure at the point of distribution was analogous to the problem of piping the natural gas. The solution to the problem of gas had been the mechanism of encased pipes. The solution to the problem of electricity was to be the transformer, a device which made possible the system of alternating current.

Word had come to him of an invention of a French electrician and a British engineer which was capable of reducing the electrical voltage to any desirable degree. He sent one of his engineers to Europe to buy the patent at any cost. The price was fifty thousand dollars. But when the invention was delivered to him, he discovered that it was in a most primitive stage, inapplicable for his purpose. And so he "turned the mechanism inside out." Within three weeks after setting eyes upon the mechanism, he perfected an efficient transformer.

He organized a company to manufacture the contrivance. And he proceeded to revamp the system of electrical distribution. Alternating current became responsible for spreading the benefits of electricity, hitherto limited to urban centers, into every farm and village in the nation.

To carry out his policy of putting electricity to work for industry, Westinghouse gathered around him some of the world's most brilliant engineers. One of them, Nikola Tesla, a Yugoslav immigrant, by harnessing alternating current to an induction motor had invented a means for converting electrical energy into mechanical energy at the lowest possible cost. This polyphase motor system was quickly put to the test.

A company had been formed to convert the tremendous energy

of the Niagara Falls into industrial power. Westinghouse was commissioned initially to install ten huge generators for an experiment. It was a complete success. Power plants mushroomed in the neighborhood of the Falls, and electricity was transmitted to nearly the entire western and middle portions of New York State as well as to large sections of Canada.

But Westinghouse's most picturesque achievement in the field of electricity occurred at the World's Fair at Chicago in 1893. The Edison and Westinghouse Companies had placed bids with the Fair Committee for the contract to light up the huge display. The Edison Company, exclusive holders of the patents to the Edison lamp, were certain they would win the contract. They submitted a bid of $13.98 per bulb. Imagine their consternation when they discovered that Westinghouse had placed a bid at $5.25 per bulb, almost nine dollars less than theirs!

To his engineers who declared that he would lose money, Westinghouse replied, "That is my intention. The advertising will be worth more than the money I lose." And when the Fair opened its gates to the astonished crowds, twelve large Westinghouse dynamos, weighing seventy-five tons each, fed alternating current into a quarter of a million bulbs.

And then this modern Prospero waved his wand and a new miracle occurred. Westinghouse, in his search for greater and greater units of power, succeeded in marshaling steam for the service of electricity. He developed a turbine which, combined with the wonder of alternating current, became the "universal burden bearer for mankind." Another of "crazy George's" hunches proved saner than the conventional ideas of the "sane." Compact, light, efficient, the turbine proved to be an ideal unit of power for ships.

Surveying the field as a whole, Westinghouse was convinced that transportation remained a weak link in the nation's industrial power. And he enlisted the magic of electricity in a new cause. He designed a motor which did away once and for all with the old

horse-drawn trolley car. He devised a special electrically-operated brake for subway trains which enabled them to stop rapidly and accurately. As a result he doubled the carrying capacity of the New York City subways alone.

Entering into partnership with the Baldwin Locomotive Works, he hitched electricity to the nation's locomotives. He sold his models to every important country in the world. The New York, New Haven and Hartford Railroad was among the first to electrify its line according to the Westinghouse system. It was followed by the Norfolk and Western and the Virginian, and later by the Pennsylvania Railroads.

VII

WESTINGHOUSE for all his commercial success remained an idealist. Throughout a lifetime of hectic business competition, his friends and associates were fiercely loyal to him and to his ideals. As the years accumulated, he harvested a wealth of honors. Union College which had dismissed him on account of his mediocre record as a student granted him the degree of Doctor of Philosophy. France, Italy, Belgium and Germany awarded him their highest decorations. And, ironically enough, the associates of Edison who had been Westinghouse's bitterest competitors until the two companies pooled their patents, bestowed a medal on him for meritorious service in the development of alternating current.

In his early sixties Westinghouse retired to his machine shop and produced his final invention. During a motor trip in his limousine—automobiles were a startling novelty at that time—his chauffeur inadvertently rode over a hole, and Westinghouse bumped his head on the roof of the car, narrowly escaping serious injury. Sobered by the experience, he set to work on air springs for automobiles that would absorb the jolts of the roads. He organized a company to manufacture the springs with as much

zest as he had assumed the directorship of his first air brake company almost half a century before. These "shock-absorbers" were universally adapted for automobiles.

This was the inventor's swan song. His body had responded faithfully to the strenuous demands made upon it for more than forty years of nerve-wracking inventing and business activity. Now it was unable to respond any longer. A heart condition compelled the inventor to retire to his Berkshire estate. Confined to a wheel chair, he investigated the means for making an invalid's life more bearable. An inventor to the very last, he spent the final hours designing a method for electrifying his "seat of torture" so that at the touch of a button he might lower, elevate, maneuver himself in any fashion he desired.

Yet he failed to complete the plan. For while he puzzled over it, death came to him at the age of sixty-eight, and sent him quietly off to sleep.

ALEXANDER GRAHAM BELL

Important Dates in the Life of Alexander Graham Bell

1847—Born, Edinburgh, Scotland.

1868—Entered London University.

1870—Moved to Canada.

1871—Became instructor to teachers of the deaf.

1873—Appointed professor of vocal physiology at Boston University.

1874—Invented harmonic multiple telegraph.

1875—Invented magneto-electric telephone.

1876—Exhibited telephone at Philadelphia Centennial Exposition.

1880—Awarded Volta prize of fifty thousand francs for electrical inventions.

1886—Received honorary degree of Doctor of Medicine from Heidelberg University.

1896—Received honorary degree of Doctor of Laws from Harvard.

1906—Received honorary degree of Doctor of Science from Oxford.

1906–12—Experimented with heavier-than-air flying machines.

1922—Died, Nova Scotia.

Alexander Graham Bell

1847–1922

BELL SUCCEEDED as an inventor because he was ignorant of electricity. "If he had known anything about electricity," wrote Moses G. Farmer, "he would never have invented the telephone."

When he told the leading scientists that he was trying to transmit human speech over an electric wire, they laughed at him. "It can't be done," they insisted. For it was impossible, they said, to send the continuous vibration of inflected speech over a make-and-break current of electricity.

"In that case," said Bell, "I shall make a continuous current of electricity to vibrate with words and music just as the air vibrates with them."

Whereupon the scientific world shook its learned head. "Crazy Bell."

But Bell was determined. He knew very little about the science of electricity, but he knew a great deal about the mechanics of speech. He was a teacher of elocution—"professor of vocal physiology"—at Boston University. "I *know* the thing can be done, and I'm going to *find the way.*"

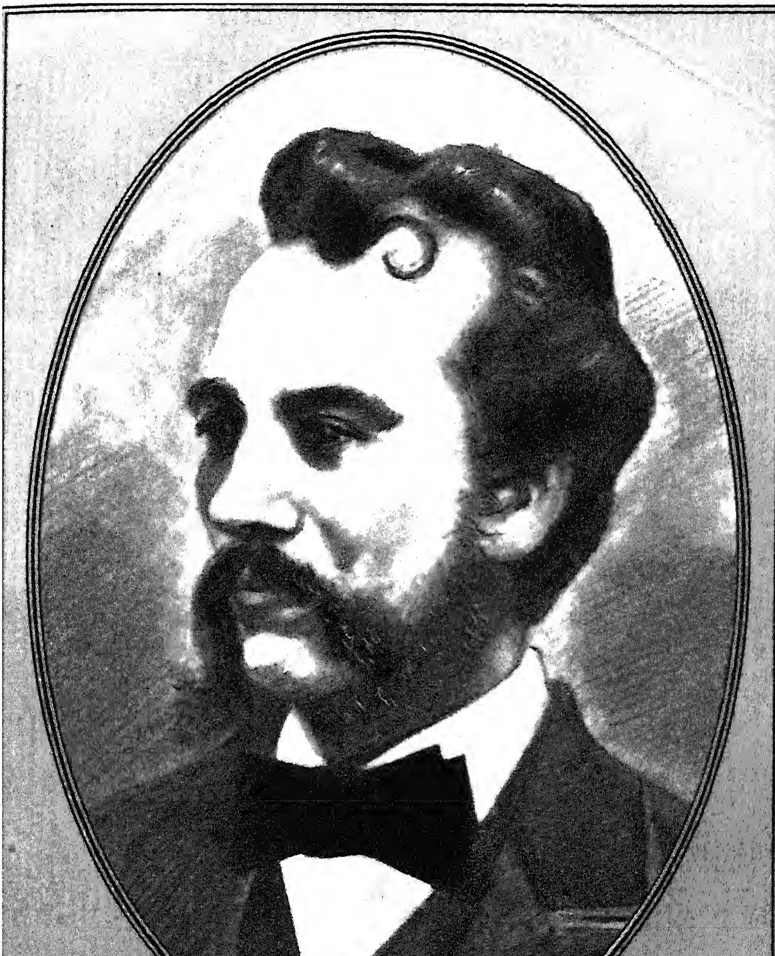
And so he "foolishly" rushed into the precincts of the unknown where the "angels" of science feared to tread.

But he explored the field with the persistency of a Scotsman and the imagination of a sage.

II

ALEXANDER BELL—he was eleven when he adopted the middle name, Graham, after an admired friend—was descended from a family of scholars and adventurers into unfamiliar fields of thought. He was the third Bell, in direct line, to investigate the mystery of human speech. His grandfather, Alexander Bell, had begun life as a shoemaker and ended it as the most famous teacher of elocution and reader of Shakespeare in Scotland. His specialty was to "correct defective utterance"—a method of his own invention—through the manipulation of the vocal cords. His father, Melville Bell, was a "professor of English diction," public reader—he was expelled from his church for a reading from "the flippant works of Mr. Charles Dickens"—and inventor of the famous system of elocution known as "Visible Speech." This system, employed by Bernard Shaw in his play *Pygmalion,* reduces to a series of "visible reproductions" or sketches, the various positions of the lips, the palate, the larynx, the nose, and the tongue in the production of the various linguistic sounds. In this way the pupil, even though he be deaf, can reproduce any required sound by imitating the speech organs of the sketch with his own organs of speech. For example, when the pupil closes his lips and passes his voice through his nose, the resulting sound is *m*—no matter what the language.

This method of visible speech produced a great impression upon the world. It was hailed as "the foundation of that dream of the philologists—a universal language." Though it fell short of this goal, the science of visible speech was instrumental in teaching young Alexander the anatomy of the human voice and—



Alexander Graham Bell

Ottmar Mergenthaler

years later—the application of this anatomy to the transmitting and receiving "anatomy" of the electric telephone.

III

As A YOUNGSTER Alexander Bell—his family called him "Aleck" —wanted to be a musician. For he had inherited an ear of unusual sensitivity from his musical mother. At home much of the talk centered on musical instruments, acoustics, and especially the mechanism of the human voice. There were three boys in the family, and all three of them were profoundly interested in the universe of sound.

Especially Aleck. It wasn't difficult for his father to persuade him that the teaching of speech would be—for him, at least—a worthier profession than the making of music. At school he devoted his interests to but one of the three Rs—reading. In all other subjects he was, by his own account, a rather "indolent and mediocre" student.

His formal schooling amounted, in all, to five years. But his informal education—at home—continued for several years longer. His father's insistence upon speech without an accent resulted in a strange phenomenon—an Edinburgh family that spoke a pure and unadulterated English.

"And it is your business, Aleck, to bring this purity of language undefiled to your fellow men."

Alexander Bell, by his father's wish and his own consent, was to become a teacher of English speech. Like his grandfather and his father, both of whom were now teaching in London. He would become their assistant, after a course of study at London University.

But his plans received a serious jolt. His younger brother died of tuberculosis. And then his older brother died of the same disease. Aleck, too, was threatened with an early death. "Perhaps the climate of America will save him," thought his distracted parents.

And so, to America (August 1870), "to give the climate of Ontario a two-year trial." The climate proved satisfactory beyond the family's dearest hopes. They never went back to England.

IV

For a year Graham Bell—as he now called himself—worked on a Canadian farm to build up his health. And then, completely recovered, he began to substitute as a teacher when his father was called away to lecture out of town.

His immediate success as a teacher encouraged his father to recommend him as a lecturer to his own audiences. And so, at twenty-four, Graham Bell was invited to lecture in Boston on the Science of Visible Speech.

A stiff and formal audience in a stiff and formal city. A city to which a "correct" florist returned hastily from a holiday at the news of the death of a "correct" citizen because it was the "correct" thing for the family "to order from the proprietor rather than from a clerk the flowers for the funeral." A city in which the ladies minded their manners, the gentlemen parted their hair in the back, and everybody gazed longingly backward to "the virtues and the traditions" of their ancestors.

Yet Graham Bell created somewhat of a sensation in this backward-looking city with his forward-looking ideas. A pleasing personality to look at, even though you didn't agree with everything he said. Tall, slender, jet-black hair and olive face and flashing eyes, he looked like a foreign nobleman amid the nobility-worshiping Bostonians. But listen to his fancies! Visible speech . . . trying to teach the deaf to talk . . . undoing the work of the Creator, who in His wisdom made these creatures deaf because He wanted them to be mute. . . .

But here and there a nod of sympathetic approval in the audience. Note, for example, the man with the long white beard and the kindly look in his eyes. He seems to be drinking in every

word. At the end of the lecture he introduces himself to Graham Bell. Mr. Hubbard, a prominent Boston lawyer. His daughter has lost her hearing from scarlet fever at the age of four. "Your plan, Mr. Bell, would be a godsend if it could succeed."

Another listener at the lecture, Mr. Thomas Sanders. His little son, George, has been born deaf. "I'd like to try your method on my child, Mr. Bell."

With the help of these men—whose children have become his private pupils—Graham Bell opens a "School for the Deaf" in Boston.

In addition to his work at this school, he secured a job as teacher of vocal physiology at Boston University.

His residence, however, was not in Boston but in the neighboring city of Salem—at the home of his patron, Thomas Sanders. Here he was graciously permitted to take over the basement and the attic for his "amusing" experiments in the "mechanics of speech." A jumble of wires, batteries, tuning forks, and other "outlandish" instruments—and in the midst of these, a tired and often hungry and sleepless Merlin, working for days on end without going out for a breath of air. Often, when Mrs. Sanders' call to dinner remained unheeded, she would slip the food on a tray inside his door. And now and then she would deliberately cut his candle short so that he would have to go to bed when it burned out.

At last his health broke down once more, and he was obliged to go to Canada for a complete rest. "No more thought of inventions, young man!" warned his doctor. "You're not built for that sort of thing."

But Bell's recuperative power was as amazing as his ability to concentrate on his work. Before long he was back to his classes and his laboratory and his dreams.

And foremost among these dreams was to make the world a happier place for the crippled children of the human family. All his scientific endeavors were the result of this single aim of his

life. He started his inventive career with "a machine"—we are quoting his own words—"that should render visible to the eyes of the deaf the vibrations of the air that affect our ears as sound." From the vibrations of the air it was but a natural step to the vibrations of the electric wire. "That machine [for the deaf] became, in the process of time, the telephone of today . . . It is only right that it should be known that the telephone is one of the products of my work at the School [for the Deaf], and resulted from my attempts to benefit the children at this School."

V

BELL'S FIRST ATTEMPT at invention resulted in the improved *phonautograph,* or *sound transcriber.* This apparatus contained an earlike membrane that intercepted sound and transmitted it into graphic waves or symbols on a surface covered with lampblack. As he continued his experiments with this instrument, he was struck—he said—"by the likeness between the mechanism of the phonautograph and the human ear."

And thus he began to study the anatomy of the ear. Through the assistance of a friend, Dr. Clarence J. Blake, surgeon at the Massachusetts Eye and Ear Infirmary, he secured the ear of a dead man and carefully examined its structure.

He took this ear on his vacation to his father's home in Canada; and there, in the summer of 1874, he began his experiments that were to culminate in the invention of the telephone.

But he was confronted with one great—the scientists insisted it was an *insurmountable*—difficulty. He was trying to transmit *continuous* sounds by a *make-and-break* current of electricity. And at this point, fortunately, it was his comparative ignorance of electricity that enabled him to persist where an expert electrician would have given up. His reason for his persistence was very simple—too simple for the complicated logic of the experts. "While I was experimenting with the human ear, I was at work

. . . on the problem of transmitting musical sounds by an intermittent current . . . and I had dreams that we might transmit the quality of a sound if we could find in the electrical current any undulations of form like the undulations we observe in the air."

Such continuous undulations, declared the academic scientists, are not to be found in electricity. But Bell, in his "sublime ignorance" of academic subtleties, believed he could find them—*and he did find them.* "I had obtained the idea that theoretically you might, by magneto electricity, create such a [continuous] current. If you could only take a piece of steel, a good chunk of magnetized steel, and vibrate it in front of the pole of an electromagnet, you would get the kind of current we wanted.

"And thus," he concluded modestly, "the telephone was conceived."

Two simple ideas—an uninterrupted current to transcribe the modulations of sound, an earlike membrane to intercept the subtleties of these modulations—and the world is encircled with the sound of the human voice.

VI

To ASSIST HIM in his experiments—for Bell was clumsy with his fingers—he hired a young mechanic, Thomas A. Watson, on a part-time basis. A partnership of mutual profit—not, at first, financially, but spiritually. Bell acquired from Watson a working knowledge of electricity, and Watson acquired from Bell a general knowledge of the world. The world of science, of literature, of art. And of music. "The best thing Bell did for me was to emphasize my love of the music of the speaking voice. He was himself a master of expressive speech."

A master, a teacher, and a transmitter of speech. Out of his scant earnings, he offered Watson a full-time job. But Watson, who was regularly employed as an electrician, turned down the

offer. "Sorry, but I can't afford to give up my eighteen-dollar-a-week job. I'll give you all the time I can spare, though."

This "spare" time sometimes lengthened into an entire sleepless night. Stringing wires, rushing up and down the steps—they now roomed in the same lodginghouse—waking their neighbors with their "tramping and their shouting," and trying to pacify the landlady, who threatened again and again to evict them unless they stopped their noise. And paid their rent.

For their experiments had so eaten into their earnings that they were far behind in their rent. Bell had made a financial arrangement with his two patrons, Mr. Hubbard and Mr. Sanders, to back him in his inventions. But thus far their backing had taken the form of encouragement rather than cash. And his own cash kept dwindling more and more. He had given up his teaching in order to devote all his time to his experiments. "I am now," he wrote to his parents (March 18, 1875), "beginning to realize the cares and anxieties of being an inventor . . . Flesh and blood could not stand much longer such a strain as I have had upon me."

He was now, to use his own expression, "in real want." His friends urged him to give up his "crazy experiments" and to go back to his teaching. But he refused to "quit." For, as he wrote in another letter to his parents (May 24, 1875), "I think that the transmission of the human voice is much more nearly at hand than I had supposed."

"A stubborn and reckless fool." And, on top of all this, he did another reckless thing. He proposed to Mabel Hubbard, the beautiful and—in spite of her deafness—accomplished daughter of Mr. Hubbard. Her father strenuously objected to their marriage. "You can't support her on magnetism and electric wires."

"This, sir, is precisely how I intend to support her." And he persisted in his wiring and his wooing until he had completed his invention and turned it into cash.

The first intimation of success came on June 2, 1875. Bell and

his assistant were "tinkering around" at the Boston shop of Charles Williams, where Watson was employed at his eighteen-dollar-a-week job. Bell was pressing the receiving springs to his ear. In another room, about sixty feet away, Watson was plucking the transmitting spring. Suddenly Bell jumped into the air. The "impossible" had come to pass. Bell had generated, by means of his magnetized steel, the continuous current of electricity that vibrated, like the air, to the various vibrations of the human voice. "At that moment the telephone was born."

The mechanism was astonishingly simple. When one spoke into the instrument, a diaphragm vibrated to the sound waves just as the ear did. These vibrations were transformed into electric signals by an electro-magnet which transmitted them to a diaphragm in a receiving instrument, setting up identical vibrations which were reproduced into the sounds of the original speaking voice. Bell's instrument served as both the transmitter and the receiver. Alternately, one talked into it and listened. (Subsequent improvements were to transform the single instrument into two.)

He tried to interest the British in his new invention before he took out an American patent. But the British dismissed the telephone as "the latest American humbug." Bell kept waiting and hoping for a change of mind in England, and neglected his application for an American patent, until he came near to losing the entire fruits of his invention. It was only a miracle that saved him.

A miracle—and the astuteness of his prospective father-in-law, Mr. Hubbard. On the morning of February 14, 1876, Hubbard decided to take matters into his own hands. Without consulting Bell—"He may be a great inventor, but he's an obdurate Scotchman"—he filed an application for a patent on the telephone, in Bell's name.

It was a lucky move. For only a few hours later the Patent Office received another claim to the invention of the telephone.

This application came from Elisha Gray, an inventor who, independently of Bell, had been experimenting along the same lines.

VII

Bell received his patent on his twenty-ninth birthday (March 3, 1876). It was a day of mental rejoicing, but not as yet of material success. For the telephone at this time was merely a toy. Nobody dreamed that it would ever become an instrument of practical use.

And thus the beginning of a new experiment for Bell. A heartbreaking struggle to compel a deaf world to hear. For the world still laughed at "Crazy Bell." Of what concern was this "silly little contraption" of his in the excitement of the Centennial Exhibition that was about to be opened at Philadelphia? Here was something real! Fireworks, brass bands, parades, games, merry-go-rounds, furs, jewels, shows, dances, songs—everything to tickle the eye and the ear. And, to cap it all, the visit of a *real king*. Dom Pedro, the Emperor of Brazil!

Graham Bell had met Dom Pedro at the Boston School for the Deaf, where he had temporarily resumed his teaching to meet his expenses for food and rent. The Emperor was interested in education, and the two had enjoyed a long chat on the subject of visible speech.

And now Dom Pedro was the guest of honor at the Centennial; and Graham Bell, one of the obscurest of the exhibitors. His telephone had been relegated to an out-of-the-way corner in the educational exhibit from Massachusetts.

Sunday, June 25, 1876. Bell had received word that on this day the judges would reach the section containing his exhibit. He had come to Philadelphia for this one day—he could spare no further time because it was the examination period at the school.

A day of terrific heat. Bell was soaked in perspiration as he adjusted and readjusted the wires of his instrument. "What if

something goes wrong!" But there's not time to think now. The judges are approaching the booth. They, too, are tired and disgruntled and hot. Accompanied by a handful of unofficial observers—among them the Emperor of Brazil—they have now reached the exhibit before his own. His heart sinks when he hears the announcement of their chairman: "This will be our last exhibit for today."

And so his telephone will not be examined today. Or *any* day. For tomorrow he must be back to his examinations in Boston.

The judges are now turning to leave. And for a moment they pause in deference for Dom Pedro to precede them. At this psychological moment Dom Pedro catches sight of the young inventor. "How do you do, Mr. Bell?"

While the judges are waiting fretfully for their imperial guest, Dom Pedro inquires about Bell's exhibit. He expresses a mild interest in the "speaking wires." He asks the judges to look at "this one more exhibit" before they go.

Reluctantly they consent. And then, the sensation of the Centennial. At one end of the exhibition hall Bell speaks into the transmitter. At the other end, five hundred feet away, the astonished judges pass the receiver from ear to ear. "The thing speaks!" Hamlet's Soliloquy—" 'To be, or not to be: that is the question . . .' "

The chairman of the committee—the famous scientist Sir William Thomson (afterward Lord Kelvin)—announces that he will speak into the transmitter himself. A dash across the hall, and then, " '. . . ay, there's the rub . . .' " At the other end another member of the committee, Professor George F. Barker: "I can hear it plainly—Sir William's voice."

At the conclusion of the test the judges were no less excited than Graham Bell. "Young man," exclaimed Sir William, "you have achieved one of the marvels of the ages. I predict that this invention of yours definitely is *to be!*"

Yet even this tribute passed over the heads of most of the

people—including the greater part of the press. The learned editors of the *Boston Transcript,* for example, dismissed the event in a supercilious note: "The experiments of Professor Bell, made in the presence of the Emperor of Brazil, Sir William Thomson, and others interested in the subject, have been highly interesting . . ."

In other words—"Those who care for such things care for such things. As for the rest of us, *we* are concerned with the *important* things."

VIII

Bell went ahead with his almost impossible task to find recognition and capital for his new invention, while society shook its collective head and lamented—"there are no men of genius in the world today." Bell offered his patents to the Western Union Telegraph Company for one hundred thousand dollars. He knew it was a great sacrifice on his part, but he was anxious to get married.

The offer was flatly refused. "Preposterous!"

Bell tried to point out that with a little improvement—which of course, required capital—the telephone could be made to transmit speech over hundreds of miles, perhaps across the entire country.

The only reply was, "Nonsense!"

And so Bell was obliged to continue his experiments with his own slender means. And with the occasional "handouts" from his backers—Thomas Sanders and Gardiner Hubbard. But the public was still apathetic. "A pretty toy, to be sure, but it has no commercial possibilities."

Yet the toy, under the skillful fingers of Watson guided by the patient genius of Graham Bell, kept growing in precision and power. Now they could talk between Boston and Cambridge—an interval of two miles; now, between Boston and Salem—a stretch of sixteen miles; and finally, between Boston and New York—a distance of over two hundred miles.

The public at last began to wake up to a new thing under the

sun. "Perhaps the thing *has* possibilities." The *Boston Post* devoted a substantial article to "Electric Telephony": "The application of this discovery promises to completely revolutionize the business of transmitting messages by electricity between distant points . . . Professor Bell is continually improving his invention, and he doubts not that he will ultimately be able to chat pleasantly with friends in Europe while sitting comfortably in his Boston home."

And now his patrons became a little more generous with their approval and their purse. Hubbard finally consented to Bell's petition for his daughter's hand. They were married (July 11, 1877), and they spent a year and a half abroad with every expectation that fame and fortune would await them on their return.

What they actually found on their return was a lawsuit that threatened to deprive Bell of all the fruits of his labors. The Western Union had purchased Elisha Gray's patents and was now trying to monopolize the entire field.

Bell was thoroughly disheartened at this new turn of affairs. He was an inventor, not a brawler. "I've had enough of the telephone. I'm through with the damn thing. I'm going back to teaching as soon as I get a job."

But for the present he was unable even to teach. The continuous repetition of his disappointments resulted in another physical breakdown. He was ordered to the Massachusetts General Hospital for a complete rest. To add to his misfortunes, he was now "hopelessly" in debt.

And then—a ray of light. The Western Union, convinced at last of Bell's prior claim to the telephone, settled the litigation out of court. The terms of the settlement—one fifth interest to the Western Union, four fifths to the Bell Company.

A ray of light between two thunderstorms—the second more threatening than the first.

This second lawsuit—or series of lawsuits—developed into the longest patent litigation in history. The longest, and the most

bitterly contested. Bell was now faced not only with financial ruin but with personal disgrace. The petty chorus of his rivals had incited a universal and unreasonable hatred against Bell. "This man is a perjurer, a fraud, and a thief!" No less than six hundred claims were entered against Bell's "infringement of other people's rights." It was an amazing example of the parasitic human desire to eat at another man's table—and to poison their host.

The altercations dragged on for years; thousands upon thousands of pages of testimony were taken; several of the lawsuits were carried to the Supreme Court. But in every case the decision was in favor of Alexander Bell.

IX

An interval of tranquillity—the patience of an understanding wife—the adoration of two impulsive daughters—and then the greatest blow of them all. This time it was a charge of "collusion and bribery" entered against him by the Attorney General of the United States. This charge, instigated by the Pan-Electric Company, represented Bell as having connived with the Patent Office personnel to give him a claim to patents which he had stolen from other inventors. And thus the Government of the United States, as plaintiff, was indicting Bell for "having perpetrated the most gigantic fraud of the century."

A most gigantic fraud it was; but Bell was not the perpetrator. In the congressional investigation that followed—amid a deluge of journalistic garbage heaped upon Bell without the slightest shred of evidence—it was established that not only was Bell innocent of the charge but that the Attorney General was personally interested in the Pan-Electric Company to the extent of a million-dollar investment in that concern.

The case was becoming too "hot" for the Attorney General and the Pan-Electric Company—especially since the backers of this company were already under injunction for infringement of the

Bell patents. The case against Bell was dropped—and from then on he was allowed to live in peace.

X

The riches and the honors—and the disillusions—of old age. The Volta prize for scientific discovery; academic degrees; medals, statues, eulogies for his "unbounded services" to mankind. "Why do they offer all this to me now—what good is it to me now? It would have meant everything to me when I was a young man."

Yet Bell's was far from a bitter old age. He had built himself an estate—Beinn Bhreagh (Beautiful Mountain)—at Cape Breton. Here he "tinkered around" with gigantic box kites, investigated the currents of the air, and shared the results of his investigations with Professor Langley, the Wright brothers, Glenn Curtiss, and others who were trying to conquer the air. Indefatigable as ever, he devoted many hours a day to his flying tests. He generally worked till three in the morning and then took a walk to the hilltop under the stars before going to bed.

Once, when invited to attend President Taft's dinner for The League to Enforce Peace, he didn't go to bed at all. For he was to be one of the speakers at the dinner, and he was afraid that he might oversleep and miss his train.

On his arrival at the hotel, shortly before six, he was so tired from the trip that he lay down for a nap. The dinner was at eight. He awoke at ten-fifteen. "I was so ashamed of myself," he explained afterward, "that I didn't even show up." Instead he went to a movie and then took the train home.

He was extremely fond of "play-acting"—a relic of his early passion for Shakespeare. One of his favorite amusements was to arrange charades for the guests at Beinn Bhreagh. And he always insisted upon taking the leading part—an ancient Jehovah with long white hair and a glittering white beard, a black tam-o'-shanter perched obliquely on his head, and his long and still-

animated figure dressed in a "working" blouse and homespun knickerbockers.

A child of elocution teachers and dramatic readers, he always dramatized himself—whether he undertook a lecture tour around the world or insisted on flying a kite in the midst of a hurricane. But always he acted his part with an eye to the future. When asked to write his reminiscences, he refused. "I am not interested in yesterday. I am interested only in tomorrow."

Always dictating scientific notes for tomorrow. When he lay on his deathbed, from pernicious anemia, he insisted upon his regular dictation. "Please don't hurry," implored his wife.

"But I have to," he murmured. "So little done. So much to do."

OTTMAR MERGENTHALER

Important Dates in the Life of Ottmar Mergenthaler

1854—Born, Bietingheim, Germany.

1868—Apprenticed to a clockmaker.

1872—Came to the United States. Settled in Washington.

1873—Moved to Baltimore.

1876—Commenced experiments with a typesetting machine

1881—Married Emma Lachenmayer.

1884—Demonstrated perfected (fourth) model linotype machine.

1888—Manufactured improved linotype machines for newspaper offices.

1899—Died, Baltimore, Maryland.

Ottmar Mergenthaler

1854–1899

IT IS INTERESTING to note that the two men who made the greatest contribution to the mechanics of printing were not printers by trade. Johann Gutenberg was a cutter of gems—a handicraft which enabled him to develop the delicacy of touch and the accuracy of vision for the designing of uniform typemolds. And Ottmar Mergenthaler was a watchmaker—a mechanical form of artistry which trained him to the precision of tempering a spring balance and to the exactitude of compounding a cohesive and resilient alloy.

Moreover, these two men who so materially expanded the horizons of knowledge were in themselves not particularly interested either in acquiring or in disseminating culture. They were merely a couple of unlettered artisans whose genius led them to the enrichment of the art of letters.

II

OTTMAR MERGENTHALER was born (May 10, 1854) in Bietingheim, an obscure little township tucked away among the hills of

Southern Germany. A sort of medieval, unmechanized, out-of-the-way corner of the world—hardly a place, it would seem, for the training of a future inventor. His father was a teacher, and his mother came of a family of teachers. The parents intended that Ottmar, too, should be trained for an academic career. Much more "respectable" to work with the head than with the hands.

But what could you do with the child? Only fourteen, and already he rebelled against following in his father's footsteps. Too hard work, too little pay, too many insults from the State Inspectors of Education. There were times when Papa Mergenthaler came home so aggravated from their "ignorant and dictatorial tongue-lashings" that he couldn't eat his supper. "No, papa, I don't want to be a teacher."

"What, then? A doctor? A lawyer? Something to keep your hands clean, you know."

But the child was stubborn. "I don't want to keep my hands clean. I like to work with my hands."

Always liked to keep his hands busy. More than any other of their five children. Ready to help in the cooking of the meals, the washing of the dishes, the building of the fires in the winter. Even insisted, against all their protests, on tilling the garden, milking the cows, and feeding the pigs.

"But we can hire a man to do the work on the farm."

"Why waste any money on a hired man? Besides, I love the work."

At last the parents resigned themselves to the inevitable. A disgrace to the Mergenthalers. A mere hand laborer in a family of teachers. "A common garden weed in a bouquet of roses." Well, at least they would inquire among the artisans and ascertain what sort of trade would be the most promising for their son.

As a result of their inquiry, they were more perplexed than ever. The carpenters complained of their hardships and advised Ottmar to become a locksmith. The locksmiths urged him to apprentice himself to a saddlemaker; the saddlemakers, to a tailor;

the tailors, to a cobbler. And so on. Everybody insisted that the other fellow's lot was better than his own.

And so the parents decided upon the simplest course. "Let Ottmar choose for himself."

"I want to be a watchmaker, like Uncle Hahl."

Uncle Hahl, his stepmother's brother, was another "ugly duckling" in their family of pedagogical respectability. "All right, then, let the two renegades work together. And live together." They apprenticed him to Hahl for a period of four years, in return for board and lodging but without pay.

Ottmar was in the seventh heaven. This handling of watches and clocks, and of other precision instruments, was like fingering the keys of a piano or the strings of a violin. Ottmar loved music —it was his one concession to culture. He had learned to play the piano at his father's school. And he liked the tick-tock of the watches, and the chiming of the clocks. Somehow, in his mind, the mechanism and the music of an instrument had become fused into a single song. "Listen to the singing of that watch-spring," he would often say to his uncle. "Isn't it wonderful?"

"Ja, ja," his uncle would reply. "But not so wonderful as your own singing."

For Ottmar had a remarkable voice. A bit uncertain in these adolescent years, but developing into a sweet and resonant baritone.

And thus, taking his life like a song, he worked his way through his apprenticeship—and became so efficient in his work that his uncle began to pay him a journeyman's wage at the end of three instead of four years.

III

1872. THE END of Ottmar's apprenticeship and of the Franco-Prussian War. The return of the soldiers to civilian life, and the resultant scarcity of jobs. Ottmar felt that he would be unable to

get the proper opening in Germany. And so he decided to seek his fortune in the United States.

He arrived at Baltimore, together with five hundred other steerage passengers, on the 26th of October. A lithe and alert young immigrant of 18—medium height, towering ambition, and amazing mechanical skill. And not the slightest apprehension as to his future in this Promised Land. For, in addition to his willing hands and his active mind, he had a third important asset—a job waiting for him in Washington. At the shop of August Hahl, the son of his step-uncle in Bietingheim. Cousin August, at his father's recommendation, had forwarded the passage money to Ottmar. "You will never regret the investment," his father had written to August.

And August never did regret it. He was engaged, among other things, in supplying the government with electrical instruments—such as heliographs (contrivances for taking photographs of the sun), implements for measuring the rain and the snow, and gauges for registering the velocity of the wind. This was a new type of work for Mergenthaler. But he mastered the job so rapidly that within two years he became the foreman and, in his cousin's absence, the business manager of the shop.

And the brains of its engineering personnel. Always suggesting improvements to other inventors or contriving inventions of his own. "At that period"—the quotation is from Mergenthaler's autobiography—"Washington was the focus for important inventions originating not only in the United States but throughout the world. The law then required that a model should accompany every application for a patent." And, since many of these models were either built or perfected in Washington, Hahl's shop was kept constantly in touch with the latest mechanical projects of the day. And these projects served as an unfailing source of inspiration to the inventiveness of Mergenthaler's mind.

A voracious appetite for problems, and an amazing ability to solve them. "The ideas and the daring of that young Ottmar!"

exclaimed his cousin to his customers again and again. "There's nothing in the world that can stop him!"

Not even the panic of 1873, when the wheels of industry had come almost to a stop. No models for patents, no new instruments for the government, and only the most essential repairs on the old instruments. "We'll have to close shop," said Hahl. "There's nothing to do in Washington."

"Then why not try another city?" suggested Mergenthaler. "Change of place, change of luck." The opportunities in Washington, he pointed out, were none too promising even under the most favorable conditions. Very little profit in the making of models for patents. Inventors are a poor lot. Not much more profit in the making of instruments for the government. "Suppose we leave Washington and open a shop in a more industrial place. Let us say, Baltimore."

Mergenthaler had a soft spot in his heart for this city—the scene of his initial contact with the United States. Baltimore, the City of Promise in the Promised Land.

But his cousin, less adventurous than Mergenthaler, was reluctant to leave an established business for a leap in the dark. "After all, Ottmar, Washington is the place where you get ideas."

"You're wrong, August." Ottmar pointed to his forehead. "*This* is the place where I get ideas."

Finally, after considerable discussion, Hahl decided to move his factory to Baltimore. His cousin, he was persuaded, had a head for business as well as for dreams.

IV

FOR A TIME, there was no improvement in Hahl's business. To Ottmar, however, this was a time not for moping but for study and play. Courses in the night schools. Mechanical drawing in his leisure hours. Singing German folk songs in a glee club of kindred spirits. And on Sundays, when the weather was pleasant,

excursions to a farmhouse for a "banquet" of sour milk, "potatoes in uniform," black pumpernickel and beer.

And always alerted for the opportunity to do something big. Not only waiting, but going out of his way to meet it. Making it his business to familiarize himself with other people's business. "Trying to invent a new threshing machine? Fine, let's study it up together. Don't know a thing about it at present. Out of my field, you know. But let's see what we can find out about it."

And, whatever the subject that came to his notice, he managed to learn more about it than anyone else.

It was thus that he came to his famous invention—the Mergenthaler typesetting machine. It started in 1876, when Ottmar was twenty-two years old. One hot afternoon in August a man by the name of Charles T. Moore brought into the shop an interesting "contraption" that he had invented. He called it a "stereotyping machine," designed to reproduce copy through typewriting and lithography. "This machine," explained Moore, "has certain defects in it; and my backers threaten to back out unless I can remedy these defects."

Moore was desperate. He was on the point of losing the labor of many years. Hahl, mopping his brow, glanced at the machine. His practiced eye told him it would be a complicated—perhaps impossible—job. At any rate, too troublesome to figure out on a hot and humid day like this. He asked the inventor to come the following day. "Perhaps it will be cooler then, and we can talk the whole thing over."

But Mergenthaler looked up from his bench. No heat or humidity could ever stop *him* from his work. "Do you mind if I examine the machine now?"

After a careful examination, he said: "I think we may be able to do something about it."

He set to work on the machine; and within a few weeks, he not only simplified the design but put it into practical shape. Moore's backers decided to go on with the invention; Hahl got

$1600 for Mergenthaler's labor; and Mergenthaler got merely a profusion of thanks.

And an idea.

V

MERGENTHALER'S idea was to design a printing machine that would avoid the defects of Moore's stereotype machine. For Moore's invention, though it could print a few copies of legislative proceedings and of other documents designed for limited use, was too crude for the reproduction of copy in larger quantities. In the first place, the matrix—or the mold for the impression of the type—was forty lines in length. Too unwieldy for practical results. In the second place, this matrix was made of *papier-maché*—a mixture of different kinds of paper pulped into a hardened dough. A mold of this material was too perishable for sustained use. As the type metal was melted into this *papier-maché*, the metal clung to the mold and the mold stuck to the metal. As a consequence, the type came out blurred and difficult to read. Frequently it was necessary to trim the type of an entire matrix—a labor consuming several hours for a single page—before it was ready to print.

If only he could produce a machine that would operate more cleanly and more quickly than Moore's invention! The idea was simple enough, but the execution was quite another matter. He talked it over with one of Moore's backers—James Clephane. "I don't propose to interfere with Mr. Moore's patent," he said. "But in the event that I *could* design an entirely different and more practical sort of machine, would you be interested?"

"Most decidedly. I'm not only interested, but I'm anxious for you to go ahead with the idea."

And so Mergenthaler started on the idea that was to revolutionize the printing of the world.

A long and often discouraging task. On several occasions he

confessed to his backer that he was ready to give up. At one time he tore up his drawings and his notes. "Mr. Clephane, it's no use. The thing can't be done."

"But it *can* be done, my young friend. And you're the one to do it!"

"Perhaps, perhaps. Just give me a little time to forget my old plans and to think up some new ones."

Old plans—long matrices, *papier-maché,* molten metal oozing into every joint and pore of the soft material, blurred copy, slow printing, loss of time and labor and money in the production of such unsatisfactory results. New plans. Modifications of the old? Or an entirely fresh start?

Ah, that was it! A fresh start. Discard the old ideas altogether. Direct your thoughts into an entirely different channel.

But what channel? And how? Experimenting, drawing, planning—day after day, week after week—and with the same negative results. One model, a second, a third—but no complete satisfaction as yet. Indistinct type, unwieldy matrices, uneven margins at the ends of the lines, and general clumsiness in the conveyance of the type to the casting mold and of the matrices back to their original position after they had performed their function. A maximum of clatter, a minimum of results. Several years of work now, and hardly any progress at all.

And then, the idea came to him—apparently out of a clear sky, but actually out of the subconscious of his own mind. For it hit at the very root of the trouble which he had recognized from the outset. Briefly and simply stated, this idea of his new machine envisioned matrices of single lines to make them wieldy, and of brass matrices instead of paper to make them strong.

A metal line of type. This, in a phrase, is the description of the machine that he had now set out to design. And, working with this idea as a basis, he developed the machine—step by patient step—until it emerged as a finished model in January, 1884. This was the fourth of the models he had constructed in the course of his

experiments. And, in every respect, the outstanding model of them all.

See him at work now as he demonstrates his amazing machine to the public. He sits at a keyboard whose touch is softer and more silent than that of any typewriter. He types out his copy—words, punctuations, and spaces—until the line is complete. And all the copy is visible to him as he works. When the line is full, he presses a lever and the matrices composing this line—with all the letters and the space-bands—are carried automatically to a position just in front of a pot of lead melted into a liquid by a flame from a gas heater. At this point the line is "justified"—that is, adjusted by the space-bands between the words until the line is equal in length to all the other lines.

And now, by means of another lever, the operator releases the liquid metal into the cavities of the letters in the matrix. And the metal, removed from the flame as it pours into the mold, solidifies almost instantly into a bar, or *slug*, with the newly-cast letters standing out in relief. The line of lead type, thus "sculptured" out of the matrices, is now ready for its final trimming before it can be ranged into a column along with the other lines.

And in the meantime the matrices, having performed their duty in the casting of the slugs, are lifted by a metal lever and carried to the top of the machine. Here they are conveyed along a horizontal bar which distributes the letters into their proper grooves or channels in the *magazine*—the receptacle for the matrices when they are not in use. For the matrices of the individual letters have *teeth* of various shapes cut into them, like so many keys; and as each key can slip only into its own keyhole, or lock, so the matrice of each letter can slip only into the channel reserved for it in the magazine.

And now that the line has been composed and cast into a metal slug, and the matrices have been redistributed to their magazine, the inventor looks up with a smile. "Well, gentlemen?"

"Most amazing thing I have ever seen!" exclaimed Whitelaw

Reid, publisher of the *New York Tribune* and one of the spectators at the demonstration.

"And the entire process," added James Clephane who was holding a watch in his hand, "has taken exactly fifteen seconds."

"All these letters and symbols"—Mr. Reid was speaking half to himself—"carried down from the magazine, arranged into sentences, adjusted, cast into metal, and carried back into the compartments at the top—*an entire line of type* in just a quarter of a minute." And then, raising his voice, he addressed himself to Mergenthaler. "Young man, I think I've got a good name for your invention. Suppose we call it the *linotype* machine."

VI

THE MERGENTHALER linotype machine is, actually, a combination of four machines working as a single unit. For it contains (1) a "typewriter" keyboard for the composition of the copy; (2) a magazine for the storing of the matrices, of which there are several hundred; (3) an apparatus for the casting of the metal type; and (4) a distributing system for the conveyance of the matrices back to the magazine.

And all the operations of this four-in-one mechanism are automatic and continuous, so that the work can go on without any hitch or wasted effort or loss of time.

This machine, perfected in 1885, was an immediate success. For it meant not only the global extension of knowledge through the medium of the printed page, but the saving of an incalculable amount of energy and capital to the printers and the publishers of the world. It invigorated the life-stream of civilization through the infusion of a new type of blood—printer's ink. To get an idea of the difference in the tempo between the old-style printing and the new, consider the hand-compositor of yesterday as compared with the linotype-operator of today:

The hand compositor was compelled to stand before a box of

about a hundred and fifty compartments. These compartments, varying in size, contained the different capitals and small letters, spaces, punctuation marks, numerals, and the like. With his right hand he picked out the letters for the words he wanted to print, and in his left hand he held a "composing stick"—or narrow metal receiver for these letters.

Now suppose he wanted to print the following sentence: "The quality of mercy" is a phrase that occurs in Act IV, Scene 1 of *The Merchant of Venice.* One by one he had to pick out of their compartments, and to put into his composing stick, the type for this sentence—the capitals and the smaller letters, the quotation marks, the spaces between the words and the wedges for the justification—for the equalization of the margins at the ends of the lines—the Roman and the Arabic numerals, the punctuation marks, the italics, and so on and on. Every single item was a separate and time-consuming operation. The fastest hand-setter wasted *an entire hour* in the composition of a book page of about 320 words—an operation which an efficient compositor on Mergenthaler's perfected linotype machine can perform in *about eight minutes flat.* "All human thought," an enthusiastic admirer remarked to Mergenthaler, "has been accelerated as a result of your amazing invention."

VII

THE SPONSORS of Mergenthaler's invention organized a company for the manufacture of his machine and offered him a royalty of ten percent on the total sales. Their chief interest, they told him, was to make as many machines, as much profit, and in as short a time as possible. "But *my* chief interest," he retorted, "is to make better and better machines all the time." They pointed out to him that they were not inventors but business men. And he, in turn, insisted that he was a business man as well as an inventor. "In the long run I will prove to you that my policy is the best."

And so there were quarrels and recriminations and bitter words between his sponsors and himself. And finally there was a break. He organized a partnership of his own—and agreed to receive, as his share, a royalty of only fifty dollars on every machine, "provided you will let me make all the necessary improvements as we go along."

The arrangement worked out to everybody's satisfaction. His partners gave Mergenthaler a free hand, and Mergenthaler gave his employees a generous wage. In this way the machine kept improving from year to year as everybody contributed his labor at his contented best. "Ottmar Mergenthaler," remarked one of his mechanics, "is not only the *brightest* but the *whitest* man I have ever met. It is the rarest privilege to work for him." And another of his mechanics observed: "There never was an employer better liked than Mergenthaler. When rush orders kept us all working overtime, he'd walk through the shop and ask us if we had dined. If we answered no, he'd order dinner from a neighboring restaurant. And often he would sit down and eat with us. For he worked harder than any of his men."

From sunrise till long after dark. He was a family man now—a wife and three children. He rarely saw them on week days. For frequently they were asleep in the morning when he left, and at night when he returned. But he was ever so tender when he did see them. And on Sundays he forgot his work and became their playfellow. He sang to them and danced with them—"I never saw such a lively creature," laughed his wife—and told them all sorts of amusing stories about his *Heimat* in Germany.

And once he took the entire family on a holiday visit to his native land. "This holiday is absolutely necessary," his physician warned him, "or your health will break down."

The good-natured irony of his old father—"Ach, what a great inventor you have become! But you might have been still greater as a teacher, like myself." The adoration of his old playmates, who basked in the glory of their childhood friendship. The bash-

fulness of the children, who sucked their thumbs as they worshiped him from afar. The delicious suppers of pigs' knuckles and sauerkraut. "You'll die of this food," his wife warned him. "Ach, nein," retorted his father. "He'll thrive on it, like the rest of us."

And the climb to the tower of Bietingheim. The examination of the old clock in the steeple—"a mechanism as amazing to me today as it was when I was a little child."

A child once more—admiring the toys of others, devising pretty toys of his own. "For what are these mighty inventions of ours but insignificant little gewgaws beside the cosmic inventions of God?"

And finally, the end of his holiday—and the return to America and his work.

VIII

VERY LITTLE TIME now left for his work. His health had been undermined in his incessant application to his typesetting machine. A harder bolt here, a softer pedal there—a stronger type distributor, a rearrangement of the various wheels and levers to make them the more easily accessible to the repairman—a contrivance for carrying the matrices to their place of assembly by means of an airblast, and then—a still better method—by the sheer force of gravity. So many details to make the machine better and stronger, the while his own body was growing wearier and weaker. A human sacrifice on the altar of science. An attack of pleurisy. It took him several weeks to get back on his feet. And then, a relapse—and tuberculosis set in.

Even now he kept assiduously at work on his machine. Better and better linotypes, more and more money, greater and greater inroads of the disease. Sick in body, sick at heart. His invention was throwing thousands of compositors out of work. He heard of the sufferings of these displaced workers. Some of them had committed suicide. In the house of one of the discharged printers, he was told, a baby had been born. But there was no money for

a crib. The entire hovel contained only a bed and a chair. All the rest of the furniture had been burned for fuel or sold for food. He sent the family a generous gift—"to give the baby a decent start in the world."

But it was only a finger trying to stop a breaking dyke. His own invention—all inventions—had set the world going at a faster pace. But at what a price! Greater progress, wider poverty; ampler knowledge, deeper suffering. "Strange how we are fated to hurt humanity when we are only trying to help it."

A compassionate heart, and bleeding lungs. They sent him to the Blue Mountains in Maryland, to Saranac Lake, to Arizona, to New Mexico—always in search of the health that was not to be purchased at any price. He spent his free moments—moments that were free from pain—in writing his autobiography. But the entire manuscript was destroyed in a fire which burned down his house at Deming, New Mexico.

He returned to Baltimore, and began to write an abridged version of his manuscript. He was engaged in this work when he died.

His entire character was reflected in the words that he spoke to those present at the passing: "Emma, my children, my friends, be kind to one another."

WILHELM KONRAD ROENTGEN

Important Dates in the Life of Wilhelm Konrad Roentgen

1845—Born, Lennep, Holland.

1869—Received degree of Doctor of Philosophy from the University of Zurich.

1874—Appointed with salary to the faculty of the University of Strasbourg.

1885—Became professor of physics and director of the physical laboratory at the University of Würzburg.

1895—Discovered the X-rays.

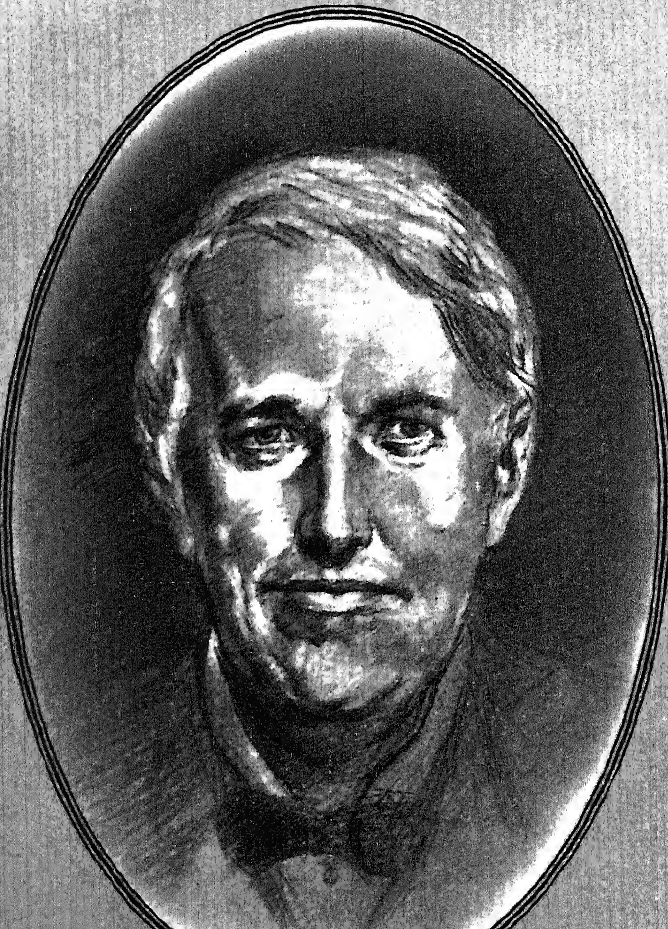
1896—Received the Rumford medal of the Royal Society.

1899—Appointed professor of experimental physics at the University of Munich.

1901—Received the first Nobel prize for physics.

1923—Died, Munich, Germany.

Wilhelm Konrad Roentgen



Thomas Alva Edison

Wilhelm Konrad Roentgen

1845–1923

In a laboratory in Würzburg, in November, 1895, a middle-aged professor of physics prepared to pass the charge of a Rumsdorf electric coil through a tube from which the atmosphere had been evacuated. He was conducting experiments to learn more about the nature of cathode rays. He rendered his tube opaque to light by enveloping it in black cardboard. Then he passed a current through the tube to satisfy himself that no ray of light had actually escaped.

He was about to switch off the current and turn to another phase of the experiment when he noticed a queer phenomenon. About three feet from the tube a faint greenish light glimmered on his work bench. Striking a match, he examined the bench. He discovered that the source of the light was a small screen, prepared with barium platinocyanide, which he had left carelessly on the bench. With amazement he picked up the screen and held it at arm's length from the tube through which he passed a second charge. Again the green light flickered. He repeated the experiment several times, removing the screen a greater and greater distance. And on each occasion the light appeared.

He was thoroughly bewildered. Not a single ray of light had escaped through the cardboard enveloping the tube. Although he was investigating cathode rays which were known to elude specially-prepared tubes, they were unable to travel more than three centimeters through the atmosphere. Yet here before his very eyes, a mysterious ray had traveled a far greater distance to light up a screen.

For weeks the German professor remained in seclusion, eating and sleeping in his laboratory, trying to understand the nature of the new ray. It had occurred to him that a ray that could penetrate a light-proof tube might pass through other opaque substances as well.

By way of experiment he placed a thousand-page book between the tube and the barium platinocyanide screen. He passed a charge through the tube and his wonder increased. The screen lit up with a greenish glow. He held before the tube a double pack of whist cards, thick blocks of wood, pine board, carbon. In each case the ray traveled through the object and illuminated the screen, although not with the identical degree of brightness.

He found to his surprise, however, that platinum and lead stopped the rays completely. Exploring why this was so, he had a startling experience. Placing a piece of lead near the screen, he was flabbergasted to observe not only the outlines of the metal, but the shadow of his thumb and fingers and, within these, the shadows of bones. The rays had penetrated the flesh and were illuminating the skeleton of a living hand!

Several weeks later, Professor Wilhelm Konrad Roentgen sat down and wrote a paper on his incredible research. "Of what nature these rays are," he declared, "is not altogether clear to me. . . . To distinguish them from others, I shall call them 'X-rays.' "

And to his wife he remarked, "When people discover the nature of my experiments, they'll say that I've gone crazy!"

II

Wilhelm Konrad Roentgen was born in Lennep on the outskirts of the Ruhr. His father, a German merchant, had moved his family during revolutionary disturbances to Holland where he became a Dutch citizen. Wilhelm was an only child brought up in the surroundings of the well-to-do. He was somewhat of a problem lad. He found it difficult to submit to the strict discipline of the Dutch educational system.

In his teens he got expelled from the Utrecht Technical School. A fellow student had painted a caricature of the teacher. While Roentgen stood in rapt admiration before it, the pedagogue entered the classroom and pounced upon him. Unwilling to divulge the name of the real culprit, Roentgen was dropped from the enrollment.

His father sought permission for him to take a private examination which would give him the necessary credits for college without graduating high school. The privilege was granted, and Roentgen prepared conscientiously for the examination. But ill luck continued to hound him. The day before the examination the teacher took ill. He was replaced by an instructor who had sat on the very board that had expelled Roentgen from school. The lad failed to receive a passing grade from this prejudiced party. And the gates of the University of Utrecht were shut to him. He was permitted, nevertheless, to attend certain classes informally, listening to lectures for two semesters. And then, on the advice of a Swiss friend, he applied for entrance to the Polytechnical School in Zürich. And he was accepted.

At Zürich he continued his haphazard methods of study. He was an erratic attender of lectures. The lakes and the mountains and the opportunities of frequent picnics were far too tempting. Roentgen, however, was popular with his fellow students. They nicknamed him "Apeldoorn" in reference to his birthplace. He

was a tall young fellow who dressed in the height of fashion. He specialized in boating picnics and mountain hikes, leading parties along the trail of the *Leiterli,* "little ladder," up the slopes of the Uetliberg, the mountain which dominated the Lake of Zürich.

Fond of the society of the drinking bowl, he became intimate friends with a local innkeeper. This proprietor, Gottfried Ludwig, was a fascinating character. A revolutionist, he had been compelled to flee Jena in the 1830's. He was a favorite of the Zürich students, instructing them in the fine points of fencing and translating their theses into Latin, in addition to filling their cups with wine.

Roentgen frequently repaired to Ludwig's tavern. And he fell in love with his daughter, Anna Bertha. He courted Anna along the *Leiterli* beside the Alpine lake. And in due course their engagement was announced. Before the wedding Anna went to live with Roentgen's mother to learn her complicated style of cooking. And when she had assimilated an assortment of recipes to quicken the palate, she wedded her fiancé on January 19, 1872.

Meantime Roentgen had continued to drift in his studies. Rarely has a man destined to add lustre to a professorship started out in so unpromising a fashion. He had specialized in engineering courses. And his professors, taking note of his lackadaisical methods of study, were convinced that he would never obtain his diploma. He managed to surprise them on this score. However, his future remained uncertain. He did not wish to devote his life to engineering.

At this juncture, Kundt, a young physics professor at the Polytechnical School, took him in hand and set him on the road to self-realization. One day he asked the young student whether he had seriously considered taking up physics as a career. He suggested that Roentgen come into his laboratory as his assistant and try his talents at it.

And so at twenty-four, the man who was to become one of the world's foremost physicists began the serious study of physics.

His duties were congenial. Kundt, his superior, was only five years older than he. The professor and his assistant relaxed from their experiments—Roentgen was not as yet married—by flirting through the window of the laboratory with some pretty girls in a tailor shop across the street.

But for once in his life Roentgen devoted a minimum amount of time to play. He tackled his laboratory assignments with zest. Burying his nose in experiments, he found a home, a purpose, a vocation.

III

MEDIOCRE as a student engineer, Roentgen became a brilliant experimental physicist. He rose to the very pinnacle of his profession. He was a master-worker with his apparatus. His success as an experimentalist was not hampered by the fact that, as the result of a childhood illness, he was left with clear vision in only one eye. In addition to this visual deficiency, he was color blind. Yet Beethoven's deafness had not prevented him from writing transcendent music. And Roentgen's semi-blindness did not hinder him from making a transcendent contribution to science.

From boyhood he had possessed a flair for developing mechanical gadgets. And now as a full-fledged scientist he constructed his own experimental apparatus. His methods were simple. He worked generally without the aid of laboratory assistants. He believed in self-dependence to the ultimate degree. A physicist should be able to accomplish a great deal with a pocket knife, he once declared.

He acquired a tremendous knowledge of the literature of physics, reading the journals long after bedtime when his daily work was done. He explored varied fields, passing from the solution of one problem to the next often without bothering to

advertise to the world the success of his investigations. He experimented with the ratio of the heats of gases. He contrived a method for measuring the conductivity of heat in crystals. He examined the absorption of heat rays in water vapor. He contributed information on the electro-magnetic rotation of the planes of the polarization in gases.

The results of his keen workmanship brought praise from his colleagues and offers of positions on the faculties of various universities. When he was only thirty-four, he received a professorship at the Hessian University at Giessen upon the recommendation of Von Helmholtz and other leaders of German science. At forty-three he came to the University of Würzburg as director of a newly-established Physical Institute.

At Würzburg he entered a new field of investigation with the wealth of correlated knowledge he had brought to his other research. He embarked upon this study with the same disinterested impulse that had led him to his contributions in gases, crystals and liquids. He had no idea that, in this instance, he would strike not merely a vein of knowledge for the professional physicist, but gold to be exploited by the layman.

For it was at Würzburg in his fiftieth year that Roentgen discovered the X-ray.

IV

For three centuries physicists had been experimenting with electricity. And they had compelled it to perform strange things for them. In the middle of the seventeenth century, Otto von Guericke had devised a barometric vacuum. Air pumps were constructed to evacuate the atmosphere from enclosed vessels. Unusual effects were noticed when an electric current was passed through the vacuum. In 1705, Hawsbee, a Fellow of the British Royal Society, agitating quicksilver in an evacuated vessel, observed the flashes of a discharge as it passed through the vapor of

mercury. Early in the nineteenth century, Faraday and Davy had further explored the radiant glows in the discharge tubes.

Several years before Roentgen, Plucker, Crookes and Hittorf conducted experiments to learn more concerning the nature of the rays given off by the production of the high-tension charges, the so-called cathode rays. One physicist, Lenard, had demonstrated that these rays could escape through the aluminum window of a glass tube. But once they eluded the tube, they were incapable of traveling far. They were almost immediately swallowed up by the atmosphere.

Now, in November, 1895, Roentgen, fascinated by the cathode rays, continued Lenard's experiments to discover additional facts about them. He had not the slightest prevision that in the course of these investigations he would discover an entirely new and even more startling ray.

Concentrating upon one aspect, the action of the rays within the evacuated vessels, he abandoned the Lenard tube with its aluminum window for a Hittorf all-glass tube. When by accident, in passing a charge through this tube, he noticed a gleam upon the barium platinocyanide screen, he immediately seized upon the significance of the phenomenon. For no known ray could possibly have escaped the tube he used to such a distance.

Yet other physicists before him, experimenting with cathode rays, had accidentally had freak experiences with the new kind of ray without realizing the significance. One American scientist had taken an X-ray photograph on February 22, 1890. But, believing it to be merely a freak exposure of a cathode ray, he had tossed it into a collection of odd photographs and forgotten about it. Roentgen alone, of the scientists who had the solution right at their finger tips, tracked down the true answer.

For weeks he carried on his investigations in secrecy. To friends who asked him the reasons for his seclusion he replied: "I have stumbled upon something interesting, but I do not know whether or not my observations are correct." He had serious misgivings

about publishing reports of a new ray that could travel through human flesh until he had bolstered his findings with absolutely convincing data.

Eventually, however, he acquainted his wife with the discovery. He persuaded her to place her hand on a casette loaded with a photographic plate and he turned his new rays upon it. When she saw with her own eyes the pictures of her bones appearing against the background of the flesh, she shivered. The experience gave her a "feeling of death."

In addition to the X-ray photos of hands, Roentgen collected other evidence for his report. He photographed a hidden wire wound on a spool; he snapped a set of weights enclosed within a box; he X-rayed a compass whose needle was encased in metal. And then he handed to the Secretary of the Würzburg Physical Medical Society for publication, a monograph, *On a New Kind of Rays, a Preliminary Communication.* He mailed reprints of his article enclosed with the X-ray photos to the leading physicists in Europe. And he awaited their reaction.

He had not long to wait. As he himself declared, "Hell broke loose!" Overnight he was thrust from the obscurity of a laboratory into the limelight. He had sent one of his articles enclosed with photos to an old friend of his, a professor of physics in Vienna. The professor, excited beyond measure, showed the sensational photographs to his guests at a house party. They fell into the hands of one of the group who, realizing their news value, brought them to the editor of a leading Vienna newspaper.

The story appeared on the front page of the Sunday edition. It was immediately cabled all over the world. Headlines in Paris, London and other cities broke the news of the marvelous new ray. Rays which penetrated opaque objects as easily as sunlight traveled through glass *were* news. Proclaimed the Frankfurter *Zeitung:* "We wish to draw attention to the significance these rays will have in the diagnosis of injuries and diseases, provided that the process can be developed so that not only the hand but

the bones of all the body can be shown without flesh." Illustrated science weeklies had a field day. They spewed forth articles garbling the facts and frequently even misspelling Roentgen's name.

Within a matter of weeks after publication of the manuscript, an X-ray industry mushroomed. Manufacturers collected Hittorf-Crookes tubes, coils and batteries and turned out portable X-ray sets for scientists, physicians and photographers. Cartoons and quips on X-rays became the order of the day. The world began to suffer from an X-ray mania. Verse writers went to desperate lengths to exploit the situation. One journal carried the following sample:

> I'm full of daze
> Shock and amaze
> For nowadays
> I hear they'll gaze
> Thro' cloak and gown and even stays,
> Those naughty, naughty Roentgen Rays.

An English firm actually blossomed forth with an advertisement of "X-ray-proof" underclothing. And a politician in New Jersey, not to be outdone, introduced a bill in the legislature forbidding the use of X-ray-treated opera glasses in theaters and music halls!

As a matter of fact, the ignorance with regard to the nature of the rays displayed by large sections of the public was appalling. One fellow actually wrote Edison the inventor: "Please send me a pound of X-rays and bill as soon as possible."

Photography fans swamped shops with demands for X-ray pictures for their albums. A woman who had been sent a Roentgen picture of a needle embedded in a foot, replied impatiently, "Photograph received, very tame indeed. Send me more sensational ones, such as the inside of the belly, back bones, brains, liver, kidneys, heads and lungs."

An unusually large quota of schemers and quacks throve on the X-ray boom. One ingenious Frenchman, realizing that many women were troubled by unwanted moustaches, came to Paris and advertised discreetly that he would remove their hair with his X-ray machine. The fair sex streamed into his office for treatment and went home to await results. But their moustaches remained with them. When they returned for an explanation, they found that their young sharper had left town with a fortune.

Another schemer announced that he had used the X-ray to change in three hours' time a piece of metal worth thirteen cents into a hundred and fifty-three dollars' worth of gold. The alchemist's millennium had arrived!

Frances E. Willard, leader of the temperance movement, announced with somewhat more sobriety that the X-ray would ultimately abolish vice in America. "By this means, drunkards and cigarette smokers can be shown the steady deterioration in their systems. . . . And seeing is believing."

Spiritualists, mediums, mystics of every brand hailed the X-ray as the finest demonstration of the existence of ectoplasm and of the other world.

It was alleged that the X-ray had given a new impulse to the study of psychology. One student reported to the press that he had produced an image of his thoughts upon a photographic plate by simply gazing at it in the dark with his "mind's eye." And another scholar reported that his dog instantly became hungry when the shadow of a bone was projected with X-rays upon his brain.

A so-called scientist in France announced that he was prepared to exhibit more than four hundred light-sensitive plates which had received a series of discharges from the human soul! He caused an immediate stir in certain circles when he published "photographs of the immortal soul."

Roentgen was appalled by this sensational response to his discovery. "In a few days I was disgusted with the business," he

wrote a friend. "I no longer recognized my own work in the reports about it. . . . Photography was merely a by-product of my experiments. But the public seized upon it as the most important thing. Eventually I became accustomed to the publicity. But it took time. For exactly four weeks after I published my manuscript I was unable to engage in a single experiment."

His house had become a shrine for reporters and curiosity seekers. One newspaper writer who elbowed his way into his laboratory suggested to Roentgen that he have his portrait painted for posterity holding his Hittorf-Crookes tube. Roentgen dismissed him politely. "I have more important things to do. I am very, very busy."

Finding it impossible to work he decided to leave for a vacation in Italy. But his notoriety hounded him even there. He was deluged with awards. The German Kaiser decorated him with the Prussian Order of the Crown. Several busts were sculptured of him. One, at the special request of the Kaiser, was placed on the Potsdam Bridge in Berlin. The University of Würzburg made him an honorary Doctor of Medicine. And the students paid him the tribute of parading with torchlights.

In 1901, the year of its inception, the first Nobel Prize for Physics was conferred on Roentgen. He bequeathed the prize money to the University of Würzburg.

Several people advised him to take out a patent and exploit the X-ray for his own financial benefit. The engineer of a German electrical firm approached him with a proposition for making money. Roentgen's reply was eloquent in its simplicity. "In accordance with the tradition of German university professors, I believe that their discoveries and inventions belong to mankind and that they should not in any way be hampered by patents."

Although his colleagues decided to call the new rays, "Roentgen rays," in honor of the discoverer, he had strong objections to the name of an individual being immortalized in this fashion. Throughout his life he insisted in calling them simply "X-rays."

But despite his modesty, the name of Roentgen became inextricably associated with the rays.

He hated pomposity. One honor bestowed on him, the Royal Merit of the Bavarian Crown, carried with it a title of nobility. But the recipient was required to make a routine application before the title was technically granted. Roentgen had no use for rank. "I have not made my application," he declared to a friend. "And I have no intention of doing so." Eventually, however, despite his protests, the designation "Excellency" was thrust upon him by court circles.

Despite the chicanery of schemers, great strides forward were taken by qualified experts in the science of the X-ray. Medicine in particular was given a powerful boost. Immediately following Roentgen's demonstration, fluoroscopes were devised which rendered visible the beating of the heart, the action of the diaphragm. Fractures, tumors, dislocations of the bones were photographed. Kidney stones and gall stones, impacted tooth roots, bullets, glass, needles in the flesh were all detected by the magic new eye.

As early as 1897 the Government of Belgium furnished all hospitals with Roentgen apparatus. Germany and Russia placed large sums of money at the disposal of researchers. The Kaiser's withered left arm was X-rayed to determine the nature of the paralysis. X-ray machines were used widely in the South African War at the turn of the century. And during the First World War, X-ray saved the lives of thousands of soldiers. In acknowledgement of this, the German Government presented Roentgen with the Order of the Iron Cross.

The outbreak of the war caught the physicist emotionally unprepared. It shook him to his depths. He was disturbed that the scientists of the contending nations had been swept away in the parochial hysteria. And yet in after years a letter came into his hands that warmed his heart. It was written by an American doctor recalling his war experiences. "We were in the trenches near Toul when we heard that the roentgenologists in the German

hospitals were celebrating Professor Roentgen's birthday. The American radiologists appreciate the discovery of the professor as much as the Germans do. We drank with French cognac to the health of the old German professor."

Roentgen had an almost prophetic insight into the evils of post-war Germany. When martial law was ordered in Bavaria in 1923, as the result of a public uprising by the National Socialists, he declared to a friend that Hitler would one day become "perhaps a second Mussolini." "I wonder whether it is not too late to lay the ghosts that have already been called forth."

His own existence was under a shadow. His wife, a companion for nearly fifty years, suffered a chronic lingering illness. She had energy only to tend the flowers in her garden. Toward the end, Roentgen gave her almost hourly injections of morphine to ease her pain. He never left her side. She passed away finally in 1919, at the age of eighty-one.

In 1920 when Roentgen retired from active teaching he was a very lonely man. During his final years he grew intensely homesick for a last glimpse of the mountains of Switzerland. "I wish to see them again before I expire." In 1922 he was invited by friends to visit Switzerland once again. And in this, his seventy-sixth year, he made a final climb of the Alps. "I still prefer to leave the well-worn path and clamber over bramble and stone. If I should ever be missing, don't search for me on the main road."

He died in his seventy-eighth year of cancer, February 10, 1923. During his illness, he took thorough notes on his symptoms, reviewed them with complete objectivity and made his own accurate diagnosis. He was an experimental scientist to the end.

If Roentgen were alive today he would be amazed at the modern techniques that are employed to exploit the high frequency, short wave, electro-magnetic ray which bears his name. He would be astounded at the machines which produce rays of two million volts compared with his own tubes of twenty thousand voltage.

Today, in medicine, X-rays are utilized not only to diagnose, but to treat many diseases. They are used to cure skin infections. They mitigate the pain resulting from malignant tumors. Neurologists, by injecting air into the spine and even into the brain itself, are able to discover by means of X-ray deep pathological changes within the nervous system. X-rays are the greatest single aid for the diagnosis of chest diseases. Every hollow organ in the body can be X-rayed by the use of appropriate "contrast media."

During the Second World War, portable X-ray machines were flown to the front and dropped by parachute for combat troops.

The Roentgen rays have been exploited for industry as well. They are an essential "eye" in metallurgy. They reveal the defects in casting, in welded metals. They examine the quality of steel armor plates and bridge materials.

Foodstuffs are X-rayed to determine their purity. Fake jewelry is discovered by the ray. Oil paintings are X-rayed for their authenticity. Textiles, plastics, synthetic rubber, all come under the eye of these powerful rays which radiate at approximately a million-billion frequency per second.

Most important of all, perhaps, has been the influence of the X-ray on the entire body of physical knowledge over the past fifty years. Its discovery has led to epochal explorations in radioactivity, cosmic rays, the electron. From the study of the X-ray has stemmed research on the quantum, the electro-magnetic spectrum, radium. The X-ray has made possible the study of nuclear physics; it has lit the way to the astonishing new era of atomic energy.

When Roentgen published his manuscript, he started nothing less than a "chain reaction."

THOMAS ALVA EDISON

Important Dates in the Life of Thomas A. Edison

1847—Born, Milan, Ohio.

1854—Family moved to Port Huron, Michigan.

1859—Became trainboy.

1862—Began to publish, for trainmen, the Grand Trunk Herald.

1863—Became telegraph operator.

1864—Invented automatic telegraph repeater.

1869—Came to New York. Invented improvements for stock tickers.

1872—Invented the kinetoscope (moving-picture machine).

1876—Moved to Menlo Park, New Jersey.

1877—Invented phonograph.

1878—Made Chevalier of the French Legion of Honor.

1879—Demonstrated invention of electric light at Menlo Park.

1879–1931—Engaged in numerous inventions. Took out more than 1000 patents.

1931—Died, West Orange, New Jersey.

Thomas Alva Edison

1847–1931

GENIUS IS the ability to do the hardest things the easiest way. One day, when Edison was working on a practical lamp for his newly discovered electric light, he found it necessary to get the cubical content of an irregular glass bulb. Too busy himself to attend to the job, he called in his most brilliant mathematician to help him. Arming himself with many sheets of foolscap, the great savant sat down to work. A week later Edison asked him how he was getting along.

"Very nicely, Mr. Edison, but I am not finished yet."

Edison looked at the formidable array of charts and figures submitted by the mathematician. "How much longer will it take you to solve the problem?"

"Oh, another week, I expect."

"Let me show you how to do it in a minute," said Edison.

He filled the bulb with water.

"Now measure the water, and you've got the answer."

II

EDISON POSSESSED not only a knack for hitting upon the obvious, but an infinite capacity for taking pains. In his effort to perfect the storage battery, he had made ten thousand unsuccessful tests on various chemical combinations. "Isn't it a shame," said a friend, "that with all this tremendous labor you haven't been able to get any results?"

"Why, man," said Edison, "I've got lots of results. I've discovered several thousand things that won't work."

Edison came by his energy from a stock of sturdy pioneers who were forever seeking for the things that worked through the discarding of things that wouldn't work. His great-grandfather, John Edison, fled from Staten Island to Novia Scotia in order to escape hanging as a Tory in the Revolutionary War. His grandfather, Samuel Edison, migrated from Nova Scotia in search of a better home and found it on the banks of the Otter River, in Upper Canada. His father, Samuel Edison—"a giant of a man" —became involved in a plot to overthrow the Tory regime in Canada and to replace it with a representative government like that of the United States. The plot was discovered, and "Sammy" Edison made his escape across trackless forests and icebound rivers —"it was my long legs that saved me"—until he found safety in the village of Milan, Ohio. Here he set up a mill and sent for his family through the kindly offices of a barge captain by the name of Alva Bradley. And here, in the midst of a blizzard on the morning of February 11, 1847, he greeted the arrival of his seventh child, a son. They christened the baby Thomas Alva—the second name in honor of Mr. Bradley.

From his very infancy Alva was preoccupied, ingenious, and ready to "learn something about everything." At six he set his father's barn on fire "just to see what it would do." It burned down to the ground, and almost burned Alva along with it. For

this, the first of his experiments, his father punished him with a public spanking in the village square.

On another occasion he tried sitting on a nest of goose eggs to see if he could hatch them. All that he hatched was an omelet on the seat of his pants. Another spanking, another discovery of the things that wouldn't work.

His entire childhood was a succession of experiments. When he was seven years old his parents moved to Port Huron, Michigan. The new Edison home had a lofty tower overlooking Lake Huron and the St. Clair River. Young Alva—Al for short—spent a great part of his time scanning the horizon through an old telescope perched on top of the tower.

Watching the heavens above, and studying the elements below. In the cellar of his house he had set up a chemical laboratory with "Poison Don't Touch" labels on all the bottles, in order to keep them away from inquisitive fingers.

"An addled youngster," said the neighbors. One day he fed an enormous quantity of seidlitz powders to his little Dutch playmate, Michael Oates. "Why did you do it, son?" asked his father. "Well, Pop," said Alva, "I wanted to see if the seidlitz powders would form enough gas in his stomach to make him fly."

The children left him alone to his "crazy" games. The elders shook their heads. Even his father thought there was something queer about him. The only one who believed in him was his mother. She encouraged him in his experiments, and on his ninth birthday she bought him a copy of Parker's *School of Natural Philosophy*. "The greatest present I ever received," said Edison of this book many years later.

He used this book not only as a basis for his experiments but as a stimulant to his imagination. And he fed his healthy imagination on many another volume. By his tenth birthday he had familiarized himself with such works as Hume's *History of England*, Sears' *History of the World*, Burton's *Anatomy of Melancholy*, Gibbon's *Decline and Fall of the Roman Empire*, and the *Dictionary of Sciences*.

Yet Al Edison was no bookworm. On the contrary, he was a very practical youngster. When the railroad was built between Port Huron and Detroit, he applied for a job as "news-butcher" on the train. A "merchant on his own" at twelve, he wasn't content with only one occupation. In his spare moments, when he had finished peddling his newspapers, he busied himself in the baggage car, writing and printing a newspaper of his own, or in a chemical laboratory which he had set up in another car. This laboratory, incidentally, cost him his job on the train and thus indirectly led to his study of telegraphy and to his first invention. One day, as the train was bumping over a rough road, a stick of phosphorus from Edison's pile of chemicals fell to the floor and set fire to the baggage car. The conductor extinguished the flames and kicked Edison out of his railroad laboratory into the bigger laboratory of the world.

Al Edison—at that time he pronounced his name *Eadison*—was not sorry to lose his job as a news peddler. In his daily trips from city to city he had become acquainted with the telegraph operators at the railroad stations. Their work fascinated him. He decided to become one of them. Devoting as many as eighteen hours a day to practice, he soon mastered the job, stretched a wire between the drugstore and the depot at Port Huron, and set himself up as a "private merchant of local messages." But the businessmen of the town preferred to receive and to deliver their local messages in person. His earnings averaged less than fifty cents a month.

Yet his knowledge of telegraphy, combined with his mental resourcefulness, enabled him to come to the rescue of his townsmen on one occasion when an ice jam had severed the wires between Port Huron and Canada. Due to the floating ice, it was impossible to make the repairs. But this did not phase Tom—he had now changed from his second to his first name. He promised to deliver the messages across the lake to Canada if they would supply him with a locomotive and an engineer. Smiling skep-

tically, the railroad authorities granted his request. But their skepticism changed to admiration when they saw the simplicity of his plan. All he did was to toot out a telegraph message on the engine in whistles of dots and dashes. At first there was no answer; but when Edison had repeated the message several times, a Canadian operator caught on and tooted back a message in reply. It was perhaps the first instance of "wireless telegraphy" on record.

A remarkably clever young fellow. And remarkably untidy. He spent his money on books and left practically nothing for his clothes. One winter he went without an overcoat and nearly froze to death. An experimenting vagabond. From city to city he drifted, and from job to job. Easily hired, easily fired. His ideas were too "crazy" for his superiors. Talked about sending two messages over a wire. "Why, any damn fool knows that a wire can't be worked both ways at the same time." This "lunatic" was a bad influence upon the other fellows in the office. "Out you go!"

And out he kept going, until finally he found his way to Boston. It was on a midwinter day in 1868 when he walked into the Boston office of the Western Union and asked for a job as a telegraph operator. The superintendent, George F. Milliken, looked up from his desk. What a disreputable-looking hobo! Pants too short and too tight and all but waterproof with smudge. Shoes torn and twisted out of shape. Hat so ragged that one of his ears protruded through a hole. Shirt a patchwork of tatters that hadn't been washed for weeks. And hair a matted jumble that seemingly had never known the touch of a comb.

Tom Edison had written from Canada to a Boston friend about this job, and the friend had shown the letter to Milliken. "If he can take it off the wire in such a script," said Milliken as he looked at the printlike handwriting of the letter, "tell him he can have the job."

But when Milliken looked at Edison, with his unkempt hair

and his unwashed shirt and his rickety shoes, he was not quite so sure of the young fellow's ability. "Come back at five-thirty," he said reluctantly, "and perhaps I'll give you a trial."

Edison came back at the appointed hour and found the clerks grinning at their desks. They had prepared a practical joke against their country bumpkin who dared to ask for a job as a city telegrapher. They had wired to one of the fastest New York operators to send a special news report of eight hundred words, and now they sat back to see the fun.

Picking up a bundle of blanks, Edison placed himself at the table assigned to him. "Ready!" he signaled, and the message began to pour in. Faster and faster came the words, but Edison was equal to the job. As his fingers flew over the sheets, he glanced up; and then for the first time he understood the grin on the other fellows' faces. So they wanted to show him up, did they? Very well, he would teach them a lesson! Opening the key of his instrument, he tapped to the galloping operator at the other end: "Come on, boy, don't go to sleep. Shake yourself and get busy with the other foot."

The New York operator surrendered, and the clerks in the Boston office rushed up to Edison and showered him with their congratulations. Right then and there they acknowledged him as the fastest telegraph operator in the Western Union.

III

"ANY DAMN FOOL knows that a wire can't be worked both ways." Again and again the skeptics kept reminding Edison of this natural "fact." But Edison persisted in his experiments and proved the "fact" to be a fiction. In the May issue of 1868 the *Journal of the Telegraph* made the announcement that Edison has "achieved the impossible." A few months later the following note appeared in the same journal:

"T. A. Edison has resigned his situation in the Western Union

office, Boston, and will devote his time to bringing out his inventions."

A daring step for a penniless young man. It meant foodless days and sleepless nights. Offers to sell his inventions, delays, refusals, disappointments, but never despair. "You wait, they will come to me yet."

And they came to him sooner even than he had dreamed. A shrewd businessman for whom Edison had once worked, General Marshal Lefferts, was watching his inventions. He saw their financial possibilities. One day he summoned the hungry young wizard to his office. "How much will you take for all your contraptions?"

Edison thought quickly. Should he ask for three thousand? He could manage with that sum for the present. Five thousand? Oh no, that was preposterous! Lefferts would most likely kick him out of the office if he dared to mention that sum.

"Make me an offer, General."

"Very well, would you accept forty thousand?"

Until he received his check, Edison wasn't sure whether Lefferts had said *four* thousand or *forty* thousand. When he looked at the check he almost fainted. What would he do with all this fabulous amount of money?

Yet the fabulous amount melted away in a fabulously short time. His experiments always ran ahead of his cash. Opening a workshop in Newark, he paid the highest possible wages for the best possible workmen. "I have one shop which employs eighteen men," he wrote to his parents, "and I am fitting up another shop which will employ one hundred and fifty men." He had no accountant and kept no books. On one hook he hung all the bills he owed; on another, all the bills owed him. "This is the simplest sort of bookkeeping. Why ball myself up with all kinds of complicated figures?"

And thus, pouring his money and his mind into the secret crucibles of nature, he went on with his experiments. Multiple

telegraphy—two, four, eight messages over a single wire at the same time. An electric stock-ticker instrument. An instrument that reproduced the human voice—"I'll bet you a barrel of apples against three dollars," he challenged the skeptics, "that this instrument will talk." An Aladdin's lamp that would light up the world with a new electric force. Crude discoveries thus far, mere foreshadowings of the miracles that he was to perform in these fields later on.

All work and work, save for a brief vacation to the "Wild West"—and time off to get married. Hardly a prepossessing bridegroom. Refused to wear white gloves at his wedding. "I've married a bear of a man," said his wife—the former Mary Stillwell—"but what an adorable bear!" Though gruff and absent-minded toward the rest of the world, he was all tenderness toward Mary.

And, later on, toward the children—Marion and Tommy. He nick-named them *Dot* and *Dash*. It was his greatest pleasure to play the clown for them in his spare moments. "He would don Mary's dresses"—we are quoting his sister-in-law Alice, who lived with the Edisons—"and romp and play around the house with the youngsters. They had a stereopticon and he would sometimes go behind the screen and stand on his head, and go through various antics to amuse them."

And there were times when to amuse his children meant the greatest physical torture. "He was a great sufferer from earache" —again we are quoting Alice—"and I have seen him sit on the edge of a bed and fairly grind holes in the carpet with the heels of his shoes, he would be suffering such pain."

A little play, much work, incessant pain, and an infinite patience—these were the ingredients which, combined with a flaming imagination, enabled Edison to transmute matter into motion and light. But most important of all, perhaps, was his extraordinary memory for details—his ability to co-ordinate apparently isolated facts into a coherent unit. Edison's memory was the

amazement of psychologists. It was almost photographic in its scope. One day, as he was working over the plans for a new mechanical device in a cement plant, he examined the old machine, went home without having jotted down a single note, and compiled a list of six hundred items in the old machine that required modification or improvement. Hardly a bolt or a screw had failed to impress itself upon the retina of his mental eye.

His retentive memory was like a well-stocked and well-organized mechanic's toolbox. Everything was in its logical place; and whenever he wanted to put several facts together, he could get at them without any waste of time or unnecessary fumbling. As a result of this faculty of orderly analysis, he was able to do more constructive thinking in a day than the average man is able to do in a lifetime.

But his inclusive memory and his ability to mold individual facts into related units would never have got him very far were it not for his endurance. As a general rule, he slept only four hours a day. "Life," he said, "is too important to waste in excessive snoring. There are too many things to be done. There are so many experiments waiting, and it takes so long to bring even a single experiment to a definite conclusion." It took him many years to perfect some of his inventions—years of incessant toil, fifteen hours, sixteen hours, seventeen hours, sometimes even eighteen hours a day. "I have no time for loafing as yet," he said on his sixty-seventh birthday. "I shall begin to loaf when I am eighty."

A sublime endurance, an equally sublime courage. In 1915 his laboratory at West Orange, consisting of six buildings, burned down to the ground. The buildings were not insured, and the loss amounted to five million dollars. "That's all right," he said, "I'll make a fresh start tomorrow morning. No one's ever too old to make a fresh start."

IV

While he was in the midst of his experiments with the electric bulb there was a sudden blackout in his own household. His wife Mary died of a heart attack. Eighteen months of mourning, and then he married again. In his personal habits he was still very much of a baby and needed someone to mother him. And fortunately his second wife, Mina Miller, proved like his first wife to be a good mother and congenial companion. It takes great patience to live with a genius. But it gives great satisfaction. Mina was able not only to appreciate his inventions but to share his thoughts. He often discussed his philosophy with her at the dinner table. He was profoundly interested in the mystery of life. He believed that every atom within the body, like the entire body itself, possesses an individual intelligence. "Look at the thousand ways in which atoms of hydrogen combine with other atoms to form the most diverse substances. Do you mean to tell me that they do this without intelligence?"

And then he went on to clarify his thought. "Atoms in harmonious and useful combinations assume beautiful shapes and colors, or give forth a pleasant perfume. In sickness, death, decomposition, or filth, the disagreement of the component atoms immediately makes itself felt by bad odors."

And the upshot of it all? The final union of the most intelligent atoms into the most intelligent substance. "Gathered together in certain forms, the atoms constitute animals of the lower orders. At last they combine in man, who represents the total intelligence of all the atoms."

"But where," asked Mina, "does all this gradual combination come from?"

"From some power greater than ourselves."

"Then you believe in an intelligent Creator?"

"I certainly do. The existence of a personal God can to my mind almost be demonstrated by chemistry."

Edison was not only a great inventor but a constructive idealist. He was interested primarily in the things that further the plans of God. In his own experiments he aimed at the inventions that serve life, and not at those that produce death. "Making things which kill men," he once said, "is against my fiber. I would rather make people laugh."

This was the principal objective of his life—to bring laughter into the hearts of the people. More laughter and greater light. "The world has been steeped in darkness long enough."

V

THE INVENTION of the electric light was the direct outgrowth of Edison's philosophy. And it was as simple in its conception as it was eventful in its result. It was one of those surprising discoveries of the obvious. If electricity can produce power and heat, argued Edison, there is no reason why it shouldn't produce light—provided we can find something that will burn properly under the stimulus of heat and power. And so he began to seek a substance, which, like the bush of Moses, would burn without being consumed. In this quest Edison was not alone. Many others, on both sides of the Atlantic, had thought of electric lighting. An American inventor, J. W. Starr, had worked on incandescent lamps even before Edison was born. Another American, Moses G. Farmer, had provided his sitting room with a number of crude electric lamps twenty years before Edison's invention of incandescent light. In England, in France, and in Russia a number of scientists were producing equally crude lamps that would flare up for a short time and then flicker out. But Edison's chief rival in the search for the secret of practical and permanent electrical illumination was W. E. Sawyer. This American inventor had much of the brilliance but little of the patience of Edison. It was

Edison who sat tirelessly in his laboratory, trying out one filament after another in his vacuum bulbs, ransacking every nook and cranny of the earth for the fiber that would give a brilliant and steady and, so far as possible, indestructible glow. And it was Edison who, refusing to admit defeat in the face of financial failure and the jeers of the scientific and journalistic world, finally discovered the magic fiber—a carbon filament which, heated in a vacuum bulb, radiated light. On New Year's Eve, 1879, a throng of people from the surrounding cities had come to Edison's laboratory at Menlo Park, New Jersey. The ground of the little village was covered with snow. Suddenly, the switch of a button, and the darkness bloomed into a silver radiance under the flood of a dozen street lamps. On that New Year's Eve the genius of Edison had for the first time in history transformed night into day.

Just before the miracle had happened, a leading New York editor had exclaimed: "It has been absolutely proved that this sort of light is impossible—it is against the laws of Nature!"

VI

Edison has been accused of being a second-rate inventor and a first-rate businessman. He capitalized, it has been said, on the inventions of others. This accusation is, we believe, unfounded. It is true that others worked simultaneously with Edison on many of the inventions for which he is credited. But Edison worked harder and faster than the rest of them. And he worked under the handicap of his chronic earaches and his deafness. Indeed, he turned his handicap into an advantage. "It takes a deaf man to hear music," he remarked when he was experimenting on the phonograph. And when he was asked to explain this paradox, he said: "Most people hear only through their ears. I hear through my teeth and through my skull. Ordinarily I place my head against the phonograph. If there is some faint sound that I don't

quite catch this way, I bite into the wood and I get it good and strong."

It was this faculty of hearing through his teeth and skull that enabled him to improve upon Alexander Graham Bell's invention of the telephone. Bell's instrument had been quite definitely a primitive mechanism, owing to the fact that it had been designed to serve both as a transmitter and a receiver. But Edison transformed it into an object of practical utility by giving it a separate mouthpiece and earpiece, instead of allowing the same tube to be used clumsily for both purposes. It sounds simple today. But it took Edison to think of it.

And many of the "simple" things that today make life worth living have had their origin in the magical laboratory of Edison's thought. Almost to the last day of his eighty-four years he worked on his experiments—an inspired, whimsical, untidy, modest, gentle, shrewd, and indefatigable Merlin. Out of his sorcerer's brain came an endless stream of electrical and mechanical servants to bring new amusements and new comforts to the human race. His inventions of the phonograph, the electric light, the motion picture, and the first crude "talkie" are merely the most popular of his hundreds of vital contributions to the applied science of the present day. His was perhaps the most universal mind in America during the nineteenth century. Once, when he visited Luther Burbank in his garden at Santa Rosa, the "plant wizard" asked him to register in his guest book. The pages of the guest book were divided into four columns, as follows:

Name	*Address*	*Occupation*	*Interested In*

Under the caption *Interested In,* Edison wrote: "Everything." He was satisfied with nothing short of the sum of practical human knowledge.

In his endless quest for the practical, he was never satisfied with his past achievement. Always he looked toward the future.

Important Dates in the Life of Rudolf Diesel

1858—Born, Paris, France.

1880–90—Employed in Paris as manager of a refrigerating plant.

1892—Took out first patent as the result of experiments with internal combustion engines.

1893—Published The Theory and Construction of a Rational Heat Motor. *Began work on the development of the Diesel engine.*

1898—Gave in Munich the first public display of the Diesel motor.

1899—Established a factory at Augsburg for the manufacture of Diesel engines.

1904—Paid first visit to America.

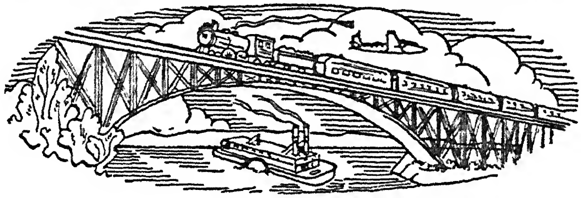
1913—Disappeared while crossing the English Channel.

Rudolf Diesel

Guglielmo Marconi

Rudolf Christian Karl Diesel

1858–1913



THE PASSING OF RUDOLF DIESEL would make an excellent climax to a motion picture mystery story. On September 30, 1913, the newspapers informed the public that the "famous Paris-born Bavarian inventor" had "vanished from the channel steamer *Dresden* on its crossing from Antwerp to London." On board with with him at the embarkation were two of his friends who accompanied him on the trip. They were on the way to an important scientific conference in England. Diesel's companions reported that they had dined with him on the steamer, had taken a stroll together up and down the deck, and then had retired each to his stateroom. The next morning, when his friends failed to see him on deck as the steamer was approaching the shore, they went to his stateroom. The bed had not been slept in. The inventor had disappeared—and with him, several important papers that he had been carrying to the conference. These papers dealt—presumably—with the possible consideration of Diesel power for the British submarines . . .

A year later, when the First World War broke out, the more imaginative journalists tried to weave an international spy plot

into the story of Diesel's disappearance. But this mysterious disappearance, as we shall see later on, was due very likely to a less lurid but more tragic cause.

II

He was descended from a long line of Bavarian craftsmen—bookbinders, tailors, cobblers, manufacturers of leather goods, and the like. His father, "an expert in the sewing of books and bags," had left his native city of Augsburg during the revolutionary upheaval of 1848. Settling down in Paris, he married a German Fräulein who was living in the French capital, opened a leather shop that gave him but a scanty livelihood, and entered into a "partnership with the Lord" to raise a family on a minimum of food and a maximum of hope. His more practical wife, however, tried to bolster his hope with an occasional contribution to the family chest. She gave private lessons in German and in English to the Parisians, and in French to the newly arrived immigrants from Germany.

It was into this tri-lingual atmosphere that Rudolf was born (March 18, 1858). His childhood was rather dismal on the whole. Tossed about between the mysticism of his father and the skepticism of his mother, he found it difficult to adapt himself to the realities of life. His father, in addition to his nebulous fantasies, suffered from a violent temper. Once, in a mood of experimental discovery for which he showed an early aptitude, young Rudolf dismantled a cuckoo clock. He was unable to put it together again; and his father, for punishment, tied him securely to one of his heavier pieces of furniture. On another occasion, when Rudolf told an untruth, his father sent him to school with a placard bearing the inscription—"I am a liar"—tied around his neck.

But, on the other hand, his father spoiled him with adulation just as he cowed him with punishment. He spoke so frequently

of his "child prodigy" that whenever Rudolf heard people mention a brilliant individual, he would run to his mother and say, "I've just heard them talking about me!"

Yet he could almost be forgiven for his vanity. For he *was* unusually bright. And unusually devout. From earliest childhood he loved to sketch natural objects and mechanical designs—a form of imitative worship toward the creations of God and the inventions of men.

A restless, passionate, groping spirit, destined from the very outset to be forever on the go. When he was only twelve (in 1870), the Prussians advanced on Paris and all the German residents were driven out of the city as enemy aliens. The Diesels fled to London; and so rapid was their flight, they had no time to prepare for a home in the British capital. It was only after a search of several weeks that they found a permanent lodging-place—two little rooms, containing one bed and a sleeping couch. Hardly enough space for the father, the mother, Rudolf, and his two sisters—Louise and Emma.

And certainly not enough money to support them. After a brief schooling in England, his parents decided to unload themselves of the burden of Rudolf. And so they shipped him off to an uncle—Professor Christoph Barnickel—who was teaching mathematics at the Augsburg Trade School. And, to make sure that the "shipment" wouldn't get lost on the way, the parents wrote Professor Barnickel's name and address on a card and tied it around Rudolf's neck.

A voyage across the channel on a wind-tossed night. "The water came in through the porthole," he wrote to his parents, "and drenched me to the skin." He arrived at Augsburg with a severe toothache and a sore throat. "But Uncle and Aunt have made a very nice impression upon me."

And he, in turn, made a very nice impression upon them. In spite of his touch of vanity, he had a sense of humor that enabled him to see himself as others saw him. "Quite a philosopher for

such a little fellow." An open face, a hearty laugh, a polite "thank-you-for-everything" sort of personality, and a pair of eyes that impelled you "at the first glance to surrender your heart to him."

He entered the trade school, studied diligently—"in Germany they make you *learn*"—spent the holidays with his uncle because he hadn't the fare to go home, decided at fourteen upon an engineering career, received at fifteen a two years' scholarship, specialized in mathematics, physics and mechanical drawing, and graduated at seventeen with the highest record in the history of the school.

His parents, in the meantime, had returned to Paris at the conclusion of the Franco-Prussian War. Rudolf paid them a visit before he entered the university. But his happiness at the reunion was marred by the death of his sister, Louise—"a brilliant pianist and lovable soul."

And now, an additional cause for unhappiness. His parents objected to his further study. "If you want to become a mechanic," declared his father, "you don't need books but a hammer and a chisel." Rudolf tried to advance the argument that theory was as important as practice. But his father was stubborn. "You haven't any money for theories. You've got to earn it with your practice."

Fortunately, however, Rudolf was able to override his father's objections. He received a scholarship to the Munich Institute of Technology. Greater application than ever, whirling headaches, and spells of insomnia. But he managed to outstrip all the other students, not only in technology but in philosophy and the fine arts.

He lived close to his parents now. For the wandering Diesels had moved to Munich. Physically, he was in daily contact with them. But mentally and spiritually, he was worlds away. His father had become completely shrouded in a mantle of nebulous mysticism. He had given up his leather manufacturing for mental healing. He announced himself as a Doctor of Magnetic Therapy,

surrendered himself to the influence of a group of unworldly visionaries, neglected his family and came dangerously close to the verge of insanity.

Added to his irrational temperament was his ungovernable temper. Rudolf found it more and more difficult to get along with him. Indeed, he began to fear that his father's proximity might unbalance his own mind. And so he stayed away as much as possible from the abstractions of his home atmosphere and took refuge in the realities of wheels and pistons and oil-sprays and cylinders and steam. The formulas and the fuels that moved the machinery of the world.

Yet he too, like his father, was a healer of sorts. A would-be reformer of a sick world through the more efficient application of its motive power. "My greatest ambition in life," he said, "is to increase the happiness of mankind through the service of machinery."

With this objective in mind, he finished his college course and was about to take his final examinations—when he suddenly fell sick. Typhoid fever.

A protracted convalescence—and six months later he was permitted to take a special examination. Again he received the highest marks in the history of the school.

Ready now to exchange his academic textbooks for the mechanical textbook of the world—to test out his theories with a hammer and a chisel.

III

It was during his college days that Diesel had envisioned his dream of a "more efficient and less expensive power" for the moving of machinery. One of his professors, Karl von Linde, had delivered a number of lectures on the inefficiency of the steam engine, with its "clumsy contraption of furnace, boiler and chimney." As a result of these lectures, Diesel made a complete study

of the history of the steam engine, its evident virtues, and its equally evident defects. Too great a waste of effort at too high a cost of fuel.

At about the same time—and again under the inspiration of Professor Linde—he became interested in an ice-making machine. This machine, a manufacturing project of Professor Linde's, gave rise to an important train of thought in the mind of Rudolf Diesel. He observed that heat can generate power when it falls from a higher to a lower temperature, just as water can generate power when it falls from a higher to a lower level. A heatfall, a waterfall—and each of them can be harnessed to move machinery in the course of its cascade. A fascinating thought, to be stored away for use as a guide to all sorts of mechanical possibilities.

On his graduation from the Munich Institute, Diesel got a job in Paris, at one of the factories where the Linde ice machine was being made. His duties were manifold: he was an engine builder, repair man, inventor, director, adviser, organizer, and purchasing and selling agent. "In this way," his professor-employer advised him, "you will get a post-graduate course in engineering—not only from the technical standpoint, but from the standpoint of the public demand for the better kinds of technique."

Diesel plunged enthusiastically into the complexities of his job. "I work like a dozen slaves, and I am determined to make good."

He had a special reason now for making good. He had taken a wife—a German girl who, following their marriage, had gone to live with his parents in Munich while he was trying to establish himself in Paris. He was anxious to "get on his feet" as rapidly as possible. For he was uneasy over her possible reaction toward his father's fanaticism. Papa Diesel was bent upon turning her into a spiritualist. "It is only the spiritualists," he declared, "who will be accepted into the Kingdom of Heaven." In order to counteract the influence of this narrow-minded doctrine, Rudolf pointed out again and again in his letters to his wife that there was no exclusive road to Heaven. "You don't have to confine

yourself to Spiritualism or Protestantism or Catholicism or Judaism in order to bestow your love upon mankind and to receive the love of God . . . Jesus didn't preach any particular creed or dogma; He preached the universal gospel of good will."

This, in brief, was the religion of Rudolf Diesel. As a scientist, he had become interested in the mechanistic theory of Darwinian evolution. But as a philosopher, he adhered to the idea of the Brotherhood of Man under the Fatherhood of God. One of his great tragedies at this time was to see a man caught in an ice machine at the Linde factory. He tried to rescue the victim—who died, however, before he could be extricated from the wheels.

Diesel hated to see suffering and death. One of his earliest inventions was an ammonia bomb which was calculated "to befuddle the enemy temporarily instead of depriving him of his life." But the world ridiculed out of existence this "impractically humane" method of fighting a bloodless war.

He turned away from the illogical passions of the human heart and went back to the unemotional logic of the ice-machine formula. "The undersigned," he wrote in a somewhat cynical memorandum for his class report, "is an ice man—the kind who attempts to produce the utmost coolness among overheated people . . . The writer has settled in Paris where he is endeavoring, as a particular aim, to cool the spirit of revenge in the hereditary enemy of Germany—and in all other men who have a foolish desire to fight."

IV

THE BURNING DESIRE of the French to avenge their defeat of 1870 was making it difficult, even twenty years later, for Germans to live in Paris. Accordingly Diesel sought for employment in his own country. He requested Professor Linde to put him in charge of his ice-making business in Berlin. The professor was only too glad to grant the request—at a substantial increase in salary. But

he attached one important condition to the arrangement. "You must refrain from contributing any of *your* ideas to *my* inventions." It was the haughty teacher dictating to his humble pupil. Diesel resented the implication; but he was so anxious to get away from Paris that he accepted the condition.

"I shall not tinker with your inventions." And Diesel scrupulously held to his bargain. But this understanding didn't prevent him from tinkering with his own inventions. A mechanism for the production of ice directly in a bottle for table use—*carafe frappé.* A motor similar to a steam engine, but propelled by ammonia gas instead of water vapor as a fuel. And—the forerunner of his greatest achievement—an engine working on the principle of internal combustion. That is, an engine *whose power became self-ignited* when fuel was injected into highly compressed air.

This idea of internal combustion, or self-ignition, was Diesel's chief contribution to the mechanics of the world. The idea had come to him as he watched the conversion of heat into a mechanical power that could manufacture ice. Wouldn't it be logical, he asked himself, to assume that the potential power of heat might be utilized in other forms of machinery? A cataract of heat, transformed into power? And ignited through compression?

He got the answer to his questions when he tested out his first engine of compressed air. And the answer almost cost him his life. For the engine exploded in the test. A practical failure, but a theoretical success. "Heated air *can* be sufficiently compressed to be spontaneously set on fire." The machine, in its very explosion, had given a thundering *go ahead* to his inventive quest.

And now, to discover the cause of the explosion and to prevent its recurrence in the construction of his next machine. The chief trouble, as he learned, was that the walls of the cylinder were not strong enough to sustain the tremendous pressure of the compressed air. He set to work, then—experimenting with cylinders of different shapes and sizes and tensions, measuring the neces-

sary amount of clearance between the top of the piston and the end of the cylinder when the piston had completed the up-stroke in the compression of the air, and trying out different kinds of fuel to discover the one that would produce the maximum of power at a minimum of cost.

And, after five years of patient trial and error, he succeeded (on January 28, 1897) in producing the engine of the "greatest thermal efficiency" in the history of science. "A motor," as he triumphantly pointed out to his wife and his three children, "which has no soot, no vapor, and no smoke . . . an invention which makes me the most powerful man in the world!"

He tried to think of an appropriate name for his engine. The Beta . . . the Delta . . . the Excelsior . . . "Why not," suggested his wife, "call it the Diesel Engine?"

V

THE DIESEL ENGINE is based, briefly, upon the principle of igniting air at its highest temperature and exhausting it at its lowest temperature. In the first of his models, Diesel drove a small quantity of coal dust fuel into the cylinder by means of compressed air, and then ignited this fuel by compressing the air in the cylinder until its temperature was higher than that of the ignition point of the fuel. In his later models, he substituted oil for coal dust. The principle, however, remained the same. In the Diesel engine the fuel and the air are mixed, and the fuel is ignited, *inside* the cylinder—a process quite different from the gasoline engine in which the fuel and the air are mixed *before they enter* the cylinder.

Thus the Diesel engine compresses a charge of air which becomes *self-ignited* through the heat of the compression, while the gasoline engine compresses a mixture of gas and air which becomes *ignited by an electric spark.* This difference means not only a far greater efficiency, but a far smaller consumption of fuel, in the operation of the Diesel engine. The main idea in the Diesel

engine is to make the air do as much work as the fuel. A minimum amount of fuel is sprayed into the air, by means of a nozzle with openings so fine—each of them measuring about one-tenth of a thousandth of an inch in diameter—that the fuel comes into the cylinder not as a liquid but as a mist-like vapor. It takes a microscopic measurement of the nozzle in order to produce this fine spray, and of some of the other parts of the cylinder in order to minimize the amount of the fuel in igniting the air and in producing the power. So microscopic indeed, and so meticulously adjusted, that out of every thousand diamonds submitted for the cutting of the dies, only five are accepted as fulfilling the necessary requirements.

The result of this fine manipulation in the harnessing of much air and little fuel is the final word, to date, in the conversion of heat into power. This "supreme mover of our modern machinery" is being put to greater and more extended uses every day—in ocean liners, locomotives, cranes that can lift a building like a toy, dirigibles, power plants, tractors, trucks. And experiments are being made even now to adapt the Diesel motor to the passenger motor vehicle. When a Diesel engine can be made small enough and light enough for the modern automobile, a new chapter in transportation will have begun. Already a few tentative trips in Diesel-powered automobiles have been made over large areas of the United States. The fuel cost of one of these trips, all the way from Los Angeles to New York, amounted to somewhat less than $7.75!

VI

On October 10, 1897, Diesel formed a company—Reisinger, Meier and Diesel—for the manufacture of his engine. His income from this company—added to the royalties he received from the concessions to other companies—made him a very rich man. "I am now," he said to his wife, "a millionaire!"

On paper. For most of his wealth consisted of stock shares and

promissory notes. In actual cash he was still far from the security of a well-feathered nest.

But he went recklessly ahead and feathered his nest—with the utmost luxury and on his future prospects rather than on his present income. When he first came to Berlin, he rented a sumptuous apartment on Kurfürstendamm—the most fashionable residential section in the city. Later, when the reality of his good fortune fell short of his expectations, he moved into a less pretentious neighborhood. But his expenses still exceeded his income. And when he finally settled down in Munich (1897), he built himself a beautiful home, but at a prohibitive price. At the entrance to the house, he ordered the builders to carve out the following inscription—*Hic habitet felicitas, nil mali intret*—May happiness dwell here, (and) nothing evil enter. But happiness was not to be had for the asking.

For Diesel, like his father, was a poet possessed by the vision of the infinite. His ideas were too vast for the tenancy of the human mind. He lived beyond his means, and he dreamt beyond the horizons of reality. He regarded himself as a citizen of the world, and the world as a unit of potential harmony. In the intervals of his exacting duties he found time to write a book on the "impending unanimity" of the human race. In this book—*Solidarity*—he envisioned the cessation of all strife, the reconciliation of the individual with his group, and the collaboration of all classes and countries and groups into a "single association of loving friends."

He had not only the vision but the personality of the Messiah. "There is a wonderful freshness about him," remarked his friends again and again—"a magic fluid that emanates from his presence." And once, when he visited a dying woman, she murmured: "The air has grown suddenly so sweet . . . like the fragrance of heaven . . ."

A creature from another world, too sensitive perhaps for the grossness of the earth. So many harassments from jealous inventors and unscrupulous business men. "It's amazing," he wrote,

"that a man should be compelled to sacrifice time, money and health to counteract the evil fantasies of others whose only object is to steal your ideas and to crush your hopes!" And such terrific headaches—always drugging himself with doses of antipyrin to quiet those stabbing pains. And the constant buffeting of his fragile body between the extremes of anticipation and despair. Those everlasting lawsuits into which he kept pouring away his savings and his energy and his health.

And what would be the outcome of it all? For himself? More especially, for his wife and his three children? Well, he would try to recoup at least *some* of his losses, for *their* sake, through investments in the stock market.

And so, he plunged heavily—and on margin—into all sorts of "securities" that were anything but secure. "He was a very child in the hands of stock brokers and investment counsellors."

And then came the day when he was close to financial ruin. He had just returned from a triumphant visit to America. Speeches, adulations, exhibitions of his Diesel motor, college degrees—a very pyramid of empty honors built upon a foundation of smoke. He looked over his accounts and checked on his investments during his absence. He found himself a famous and fleeced lamb.

But he kept his troubles to himself. He would still manage to put on a bold front before the world. And before his family. He was too proud to beg for help or to reveal himself as the failure that he was.

In the summer of 1913 he took a vacation, together with his twenty-four-year-old son, Eugene, in the Bavarian Alps. Towering mountains, puny men. On this trip he partially opened his heart. "How foolish of us to entertain too lofty ambitions!" he remarked to Eugene one day. And, on another occasion, "Better no success at all, than a small measure of success with so many heartaches." Only once did he give a definite hint of the pain that was gnawing at his vitals. "Don't be disappointed, Eugene, when you see my will."

"But why talk about a will, Father? You're only fifty-five."

"Yes, yes, of course. But one can never tell . . ."

VII

WHEN HE boarded the *Dresden* for England, on September 29, 1913, he posted a farewell message to his son. *Gruss und Kuss. In inniger Liebe, dein Vater.* Greeting and a kiss. In fondest love, your father.

Hail, and farewell . . . A few days after his disappearance in the channel, Eugene stood on the shore and offered—in behalf of the family—a silent requiem to the man who had brought them honor and who had departed in order that he might bring them no disgrace.

When Diesel's safe at Munich was opened after his death, it was found practically empty.

GUGLIELMO MARCONI

Important Dates in the Life of Guglielmo Marconi

1874—Born at Bologna.

1895—Began experiments with electromagnetic waves.

1896—Took out, in England, first patent for wireless telegraphy.

1897—Established wireless communication from land to sea.

Organized Wireless Telegraph company.

1898—Established wireless communication across the English Channel.

1899—First sea rescue (of East Goodwin Lightship) *through wireless.*

1901—Established wireless communication across the Atlantic.

1902—Patented the magnetic detector.

1905—Patented the horizontal aerial.

1909—Received Nobel Prize for physics.

1912—Introduced the "timed spark system."

1918—Sent first message from England to Australia.

1937—Died.

Guglielmo Marconi

1874–1937

"Che orecchi grandi ha"—"What large ears he has!" exclaimed a relative as she saw the newborn babe.

"With these ears," said his music-loving mother, "he'll be able to intercept the still small voices of the air."

And from infancy Guglielmo grew up to be a studious, introspective and dreamy child. From his Irish mother he inherited his imaginative mind; and from his Italian father, his restless hands. And with these restless hands he was able to transmute his dreams into realities.

He was born (April 25, 1874) at Bologna. "This city," said an ancient oracle, "will enrich the world with two great gifts—one for the palate, and one for the mind." His prophecy turned out to be true. For it was a Bolognese butcher who invented the sausage—named *bologna* after the city of its origin; and it was a Bolognese scientist whom Destiny was now educating for the invention of the wireless.

Marconi received his entire education from private tutors. His father, an expert and wealthy agriculturist, was unwilling to en-

trust his delicate child to the public schools. Curled up in the library of his father's estate at Pontecchio, near Bologna, Guglielmo devoured hundreds of books upon all sorts of subjects. He was especially fond of reading about steam engines and electricity and chemistry. And always he tried to put his reading to the test. "Yes, that's what they say. But how will I know until I try it for myself?" In one of the attics he fixed up a little laboratory—"a magician's workroom." And one day he became attracted to the larger laboratory of the outdoors. He tried to extract nitrate from the atmosphere. This experiment resulted in failure, but it turned his attention to the treasure-house of the air. There were so many sounds that rippled over the air-waves—his large ears were unusually sensitive—such a labyrinth of syllables that waited to be captured and disentangled and rearranged into a definite sense. What happened to all the words that people were uttering, casting them into the air like so many pebbles into a lake? Were these words forever lost, or did they keep floating over the earth, just waiting for some instrument to recapture them?

And once, as he turned these thoughts over in his mind, he read an article about the experiments of the German physicist, Heinrich Hertz. His heart leaped up within him. Here at last was a clue to the mystery! Professor Hertz had invented an electric oscillator which could throw a spark from one end of a room to another without any visible connecting link. How did this spark travel across the room? Over an air-wave apparently, like a piece of wood floating over a water-wave in a lake. If this should prove to be true, wouldn't it be possible to direct a sound from one spot to another, just as a boy might direct a piece of wood over the surface of the water? And if an electric spark or a sound could be made to leap across a room, couldn't it also be made to leap across a field, a city, a country, a continent, perhaps even an ocean? The distance that a sound could travel over the air would depend upon the power of the electrical push, just as the distance

that a piece of wood could travel over a lake would depend upon the power of the boy's hand-push.

The thought was terrifying in its simplicity. "It was so elementary, so obvious in logic," remarked Marconi years later, "that it seemed difficult to believe no one else had thought of putting it into practice. I argued, there must be more mature scientists who had followed the same line of thought and arrived at almost similar conclusions. From the first the idea was so real to me, I did not realize that to others the theory might appear quite fantastic."

A vivid dream. And the boy inventor—he was only twenty at the time—proceeded to see whether he couldn't make it real. Impulsively he rushed in where the greybeard professors feared to tread. Together with his brother, Alfonso, he built a crude apparatus with which he tried to ensnare the elusive Hertzian spark. But in vain. Again and again he rebuilt his instruments, and rearranged them, but always with the same negative results. "The greybeards must be right, after all."

He had grown pale and drawn in his efforts. His father begged him to desist from his "crazy" dreams and to settle down to a "practical" job. Even his mother warned him that he was headed for a nervous breakdown. As for the friends of the family, they looked upon him and shook their heads. "Most likely he will land in the insane asylum."

"Ma non mi persi di coraggio"—"But I did not lose my courage." He went right ahead with his "insane and useless experimentations"—and one day he announced that he had a surprise for his parents. Inviting them into his attic workroom, he pressed a button whereupon a bell buzzed in the living room two stories below.

"But how did you do it?" asked his mother. "There are no connecting wires."

"That's just it. I have invented the wireless transmission of sound."

"God bless you!" exclaimed his mother as she embraced him

with tears in her eyes. But his father merely turned away with a contemptuous shrug. "So you've invented wireless," he said. "So what?"

II

Signor Marconi was skeptical about his son's work. Yet his generosity got the better of his skepticism. He contributed a sum of 5,000 lire (about $1,000) for his son's further experimentations with that "crazy contraption of his." Guglielmo was elated. "With this sort of encouragement, I shall encircle the world with my voice."

"See that it enables you to encircle your body with your rags," smiled Signor Marconi. "Your invention seems to me of no practical value whatsoever."

"Maybe so. But we shall see." And Guglielmo went resolutely ahead with his experiments.

It was a time (1892–1895) of great scientific expectation. The leading physicists felt that they had arrived at the borderland of revolutionary discoveries. Especially in the medium of electricity. The opaque was becoming transparent. An electric ray could be made to pierce through a granite rock or a solid wall. "Here," wrote the eminent English scientist, Sir William Crookes, "is unfolded to us a new and astonishing world . . . Here is revealed the bewildering possibility of telegraphy without wires . . . This is no mere dream of a visionary philosopher. All the requisites needed to bring it within grasp of daily life are well within the possibilities of discovery, and are so reasonable and so clearly in the path of researches . . . that we may any day expect to hear that they have emerged from the realms of speculation to those of sober fact."

This prophecy, made by an Englishman, was first fulfilled in England. The Italian government had refused to encourage Marconi in his experiments; and so the twenty-two-year-old inventor, accompanied by his mother, set out for London. Here he found a

sympathetic ear, and a public amazed at his wizardry. "What," asked a reporter, pointing to Marconi's instruments, "do you propose to do with them?"

"I propose to send signals over the air."

"Even through a fog?"

"Yes."

"Do you mean to tell us that your signals will penetrate anything and everything?"

"I am forced, as a result of my experiments, to believe so."

And he went on to prove the validity of his belief. At first he sent his messages over a distance of 100 yards; then, by "pumping" more and more power into the transmitter, he extended the distance to three miles, eight miles, eighteen miles. And then, on March 27, 1899, Marconi pressed the sending-key of a wireless which he had set up at Wimereux, a village on the west coast of France. Across the channel, at Dover, an assistant was "listening in." A few moments of tense silence, and then a return signal over the wireless from Dover to Wimereux: "Your message received. Perfect."

The bystanders overwhelmed Marconi with their congratulations. But the young inventor brushed them aside. He was too busy for all these superficialities. "Now that we have conquered the channel," he said simply, "our next job is to tackle the sea."

III

The English government issued patents to Marconi; and a group of English businessmen organized for him a Wireless Telegraph and Signal Company, with a capitalization of 100,000 pounds. Thus encouraged, Marconi went on with his experiments. He established a series of stations along the coastline of England, and he equipped a number of vessels with broadcasting instruments. In this way he made it possible for the vessels to report their positions from time to time and to call, whenever necessary,

for help. Even the skeptics were now becoming slowly convinced. "There's something in this wireless after all."

And one foggy night in April, 1899, came the first real test as to the value of wireless telegraphy. In the heavy darkness the steamer *R. F. Matthews* collided with the *East Goodwin Lightship*. A frantic signal into the air, and the miracle happened. The signal was intercepted, lifeboats were sent to the stricken vessel, and the entire crew was saved.

Thus far, however, Marconi had succeeded only in short-range communications. To be sure, he had dreamed of spanning the Atlantic with his wireless. But such dreams, believed the sober-minded academicians, were preposterous. When S. S. McClure printed in his magazine an article about the achievements and the expectations of Marconi, a professor at Clark University called the publisher to task for "foisting such absurdities upon the public." It was impossible, insisted the professor, for wireless telegraphy to travel over long stretches of the earth's surface. "The laws of physics are against it." The earth is round; but the Hertzian waves, maintained the professor, lead straight up into the air, or at most travel off at a tangent away from the curvature of the earth. Thus a wireless message, broadcast—let us say—from New York, might travel to Jersey City, or even to Newark; but beyond that point, it would trail away from the earth on a tangent into infinity.

Such were the cocksure theories of the academicians. But the experiments of Marconi knocked these theories into a cocked hat. They demonstrated a very strange and very important property of the Hertzian waves. *These waves flow over the ocean of the atmosphere in a curve that is parallel to the curvature of the earth.* "The Hertzian waves, therefore," insisted Marconi, "will eventually carry a message, just as the ocean waves can carry a ship, all the way around the earth."

And he proceeded with his experiments to transmute *that* dream into a reality. Little by little he extended the range of his

wireless to twenty-five miles, fifty miles, seventy-five miles. But to Marconi, these experiments were merely a relaxation that fitted him for further efforts. His fixed purpose now was to span the Atlantic with his wireless. "Do you really think this is possible?" asked a reporter.

"I cannot think otherwise," replied Marconi. "All we have to do is to build a transmitter powerful enough to hurl the waves across the sea."

IV

THURSDAY, December 12, 1901. Marconi, frail, sad, keen-eyed, thin-lipped, is sitting at a desk in the John Cabot Memorial Building—a bleak tower upon a bleak hill on the Newfoundland coast. He holds a telephone receiver close to his ear and gazes through the window over the thundering Atlantic. The waves are too blustery today. Will he be able to intercept the wireless that is about to be flashed across for the first time from England to America? For a moment he takes his eyes off the horizon and looks up into the air. A kite, driven by a heavy wind, is tugging violently at a copper antenna that holds it fastened to a pole. Will the slender wire stand up against the fury of the storm? On several previous experiments the kite had been torn away from its mooring. But this must not happen today. Two continents are awaiting the outcome of *this* experiment—and almost universally with an attitude of cynical disbelief. *"Of course it can't be done!"*

Marconi waited and wondered. *He* knew that it *could* be done. And yet . . .

The signals in England were to begin at 3 o'clock English time—that is, at 11:30 Newfoundland time.

Half-past eleven. Twelve. Twelve-fifteen. Marconi sits glued to the earphone. No sound other than the lashing of the wind. Perhaps he was wrong after all? Perhaps the skeptical public was right?

Twelve-twenty. Twelve-twenty-five. Twelve-twenty-nine. How slowly the minutes dragged! It looked as if the whole thing would be a fiasco after all. Wouldn't the public have a good laugh over it? Another pseudo-scientist with his crazy dreams . . . Oh, well . . .

Twelve-thirty. Marconi grew suddenly tense. Were his senses deceiving him? No, there they were. Three clicks, faint but unmistakable. The signal agreed upon—the Morse code for the letter *S*.

Marconi went back to his hotel, but spoke to no one about the amazing news. He first wanted to verify the experiment on the next day, and on the day after that—he had arranged with his assistant in England to repeat the signal on three successive days. On every one of these occasions the experiment was crowned with equal success.

He was now ready to make his statement to the press. On December 15 the *New York Times* featured the historic words: "Guglielmo Marconi announces . . . the most wonderful scientific development of recent times. He states that he has received electric signals across the Atlantic Ocean . . ."

And while the world thundered its praise, Marconi went quietly on with his work.

V

In March, 1905, Marconi took a vacation from his work. He married an Irish noblewoman, Beatrice O'Brien, daughter of Lord Inchiquin. A brief enchanted honeymoon, followed by nineteen years of disenchantment. Marconi was not the domestic type. He belonged too much to the world to cultivate the patient intimacies of a happy marriage. Though the union resulted in three children, it was finally dissolved (1924). A second marriage (1927), this time to a beautiful Italian, the Countess Maria Cristina Bezzi-Scali, proved to be more successful. Marconi had

learned to play as he grew older—he bought a yacht, the *Elettra,* which served him both as a laboratory and as a pleasure palace—and his newly acquired ability to relax resulted in quieter nerves and a less irritable temper.

The rest of his life was a continual process of growing young. "Science," he said, "keeps one forever youthful. I cannot understand the savant who grows bowed and yellowed in a workroom. I like to be out in the open looking at the universe, asking it questions, letting the mystery of it soak right into the mind, admiring the wonderful beauty of it all, and then think my way to the truth of things." He lost his right eye in an automobile accident, and remained unbowed. He won the Nobel Prize—the highest of awards—in physics, and remained unspoiled. And it was in this courageous and unassuming pursuit of his experiments, the perfection of the wireless and the conception of its even greater offspring, the radio—dreams to encircle the globe, to reach the ear of someone listening in upon another planet ("even *this* may some day be possible, who knows?")—that death overtook him on the *Elettra* (July 20, 1937). "And he embarked upon another ship to continue his explorations in another sea."

THE WRIGHT BROTHERS

Important Dates in the Lives of the Wright Brothers

WILBUR WRIGHT

1867—Born, Millville, Indiana.

1903—Constructed first successful airplane.

1904–08—Continued successful airplane experiments.

1908—Won Michelin Prize in France.

1909—Flew from Governors Island to Grant's Tomb and back. Received gold medal from French Academy of Sciences.

1912—Died, Dayton, Ohio.

ORVILLE WRIGHT

1871—Born, Dayton, Ohio.

1888—Finished high-school education.

1903—Finished, with Wilbur, first successful airplane.

1905—Made first long-distance flight near Dayton, Ohio.

1909—Received gold medal from French Academy.

1915—Sold his interest in Wright Aeroplane Company.

1917—Awarded Albert Medal from Royal Society.

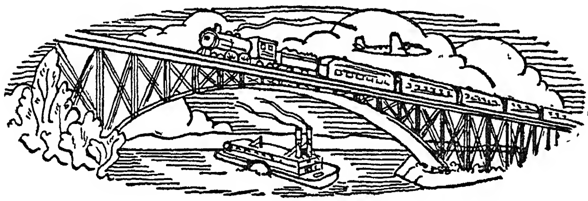
1920—Won John Fritz Medal.

1925—Received John Scott Medal.

1948—Died, Dayton, Ohio.

The Wright Brothers

Wilbur Wright, 1867–1912
Orville Wright, 1871–1948



On December 17, 1903, Orville Wright made the first historic flight in a heavier-than-air machine. Five years later, after many successful flights witnessed by hundreds of spectators, there were a number of scientists and editors who were still unconvinced. "Human flight," wrote Professor Simon Newcomb, "is not only impossible, it is illogical." And the editor of one of America's leading magazines returned a report on an authentic flight with the following comment:

"While your manuscript has been read with much interest, it does not seem to qualify either as fact or fiction."

II

In spite of its terrible destructiveness in war, the airplane, we believe, will prove to be the instrument that marks the shortest distance between human hearts. For this instrument will have succeeded more than any other in drawing the earth into a unit, in combining widely separated communities into a friendly next-

door neighborliness. The airplane is the final conqueror of time and space and isolation. In 1852 it took Ezra Meeker six months to travel by ox team over the Oregon Trail to Washington. In 1924 this ninety-three-year-old pioneer sped over the same distance, by airplane, in one day.

III

FOR THOUSANDS OF YEARS the secret of air travel had eluded the ingenuity of the world's greatest scholars. Yet the magicians who finally discovered it were two uneducated bicycle mechanics. Wilbur and Orville Wright were the sons of a clergyman. Their two older brothers and their sister were college graduates. But they themselves had only a few years of schooling. Like Benjamin Franklin, Walt Whitman, Mark Twain, Thomas Edison, and Henry Ford, the Wright brothers proved that a college degree is no passport to immortal achievement.

But if Wilbur and Orville Wright were no scholars, they were, in the true sense of the word, poets. A *poet,* by its Greek definition, is a *maker,* a *creator,* a man who transforms dreams into actualities—in short, an *inventor.* There is very little difference between the creative genius of a Shakespeare and inventive faculty of an Edison. The one forges dead syllables into a living poem, and the other combines lifeless materials into a throbbing machine. The process is the same—the fusing of odd old bits of memory into some hitherto-undiscovered aspect of the sublime.

The Wright brothers shared in this faculty of fusing old memories into new discoveries. Like Edison, they developed at an early age an almost uncanny ability for remembering details. Added to this, they both displayed a passion for mental and physical gymnastics. It was his excessive fondness for "idle" reading and for athletics that prevented Wilbur's graduation from high school. But their reading helped them to spread the wings of their imagination. And their athletic training enabled them to

come safely down to earth when they took their first ride on the bucking bronco of the air.

The two boys became interested in flight when their father one day brought them a mechanical toy called a *helicopter*. This "flying top" had two propellers that caused it to whizz into the air when it was wound up. The two boys took the helicopter apart, put it together, and then took it apart again, in order to discover the secret of its flight. They noticed that the propellers of this toy pushed against the air just as the paddles of a boat push against the water. Throwing the dismantled toy into a rubbish heap, they stored up in their memory the lesson that they had learned from it.

Later they watched the flight of a box kite, and then they turned to the birds. For hours they would lie on their backs, their eyes intent upon the lifting and the drifting of the wings against the sky. They noticed that some of the birds, especially the sea gulls, had a slight warp, or dip, to their wings. It was this warp, they observed, that enabled the birds to maintain their balance and to make their turns in the air. This fact, too, the boys carefully stored away in their memory for future use.

A couple of restless youngsters, with observant eyes and active minds. And fingers always on the itch to be puttering with tools. They built and sold kites for pocket money, constructed a wooden lathe with a foot treadle and with marbles for ball bearings, invented an improvement on a hay-baling machine, and designed an original device for folding newspapers. All this before they were out of their teens. "The boys," said their teachers, "are bright, but they are unable to concentrate on their school textbooks." True enough. Their minds were centered upon the far more important mechanical textbook of the universe.

Their thinking was almost entirely extracurricular. They delved into the mysteries of nature. They pondered upon one of the most baffling of these mysteries—the sustaining power of the air. They began to read up on the history of man's attempts at flight. They learned about the mythical wings of Icarus, the crude experiments

of Leonardo da Vinci, the enthusiastic but fruitless efforts of Chanute, Mouillard, Ader, and Lilienthal, and the scientific researches of Maxim and Langley. They noted that there were two schools of thought with regard to the possible conquest of the air—those who believed in the kitelike gliders, and those who experimented with the birdlike motor machines. They decided to begin their own experiments with the motorless gliders.

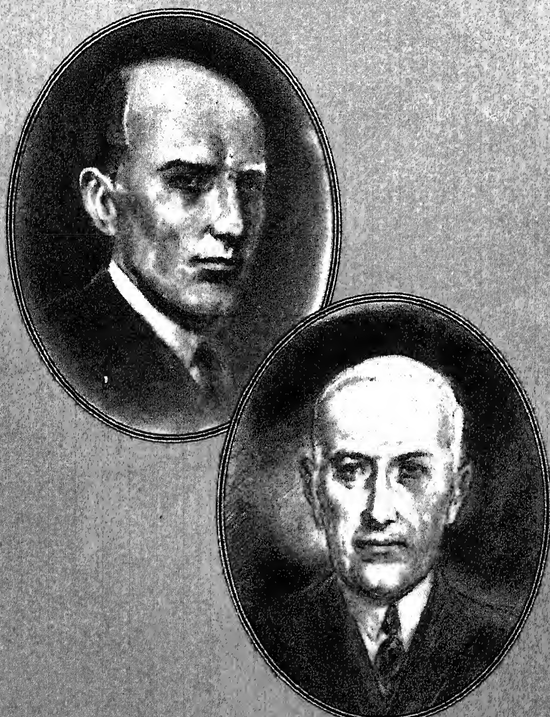
From the very start they found themselves handicapped. Men like Ader and Maxim and Langley had the advantage of a large working capital for their experiments. But the only capital in the possession of these two young mechanics—they had opened a bicycle shop at Dayton, Ohio—was an inexhaustible supply of enthusiasm and a daredevil willingness to take risks.

With these two assets, Orville and Wilbur set to work in the back yard of their bicycle shop, laying their "crazy" plans and collecting homespun and rubbish for the building of their first glider. "And with this contraption," laughed their father, "you expect to conquer the kingdom of the birds!"

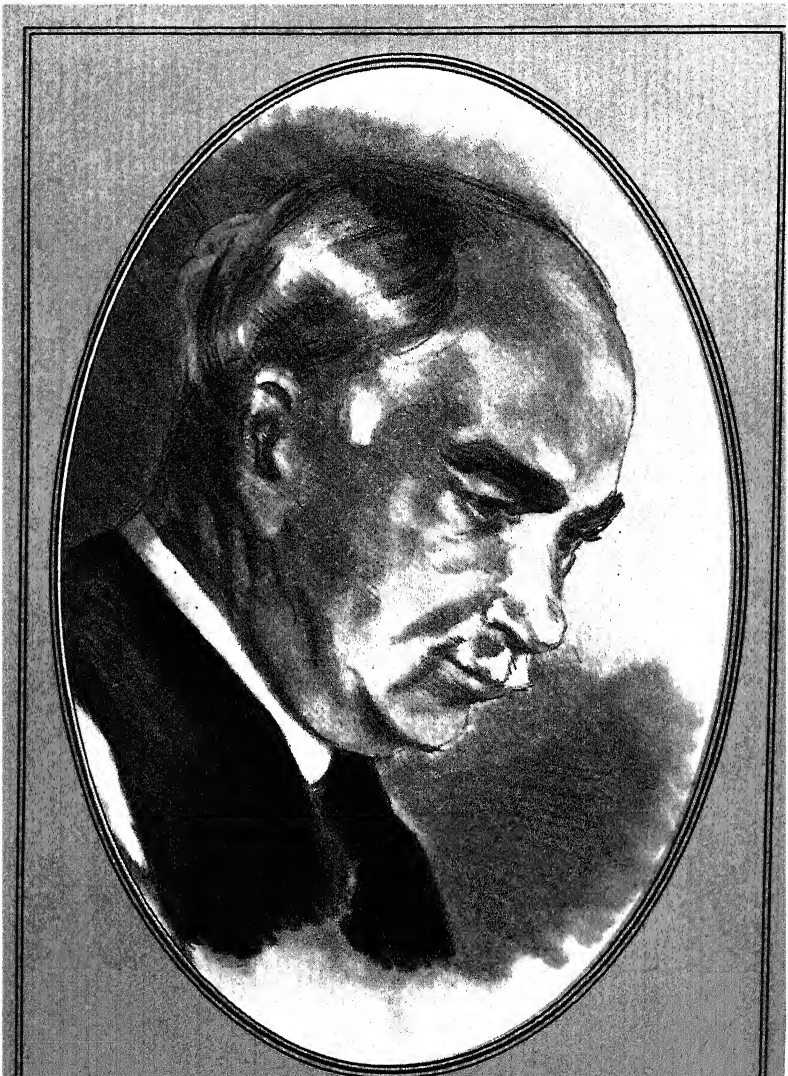
The neighbors shared the good-natured ridicule of the father. So the Wright boys were planning to fly, were they? Well, it couldn't be done! Men were meant to stay down on the earth. Otherwise they'd have been given wings. And that was that!

But the Wright boys believed they could do it. They had made an intensive study of Lilienthal's papers on *The Problem of Flying and Practical Experiments in Soaring.* True enough, Lilienthal had been killed in a crash of his gliding machine. But before his fatal accident he had made several successful hops through the air in his glider. "What Lilienthal has done with a glider, we can do with a motor machine."

First, however, they would begin where Lilienthal had left off—with a gliding machine. They had studied the causes of Lilienthal's failures—and these failures had been far more numerous than his successes; they had calculated the lifting and the balancing power of flat and of curved wings; they had



The Wright Brothers



Lee De Forest

measured, by means of a funnel which they had invented for the purpose, the pressure of the air on moving bodies; and they had reached the conclusion that the secret of aerial navigation lay in the proper equilibrium between the airship and the air. And thus they completed their first scientific glider—at a cost of fifteen dollars. It was a peculiar-looking object—a box kite of cloth and wooden ribs that resembled an enormous chicken coop.

In order to try out this glider, they asked the Weather Bureau at Washington to recommend a spot where they could find steady winds, low hills for take-off, and soft sand dunes for landing. Willis L. Moore, chief of the bureau, informed them that Kitty Hawk, North Carolina, was such a spot.

Here the two brothers took their aircraft on September 25, 1900. And here, without any fuss or witness, they began their practical experiments. At first they tried to send their glider up like a kite. It took to the air without any trouble. Their calculations had been correct. There was plenty of *lift* to the creature. Then they proceeded to the next step. Pulling their wood-and-canvas Pegasus down to earth, they prepared it for its first aerial ride with a human being upon its back. Wilbur stretched himself out on the lower wing, face down, took the controlling reins in his hands, and the next minute found himself flying through the air.

It was one of the strangest experiences within the memory of man. Wilbur Wright had set himself adrift in the Nowhere, without any roads to guide him and without any anchor under his feet. It was a terrifying moment. He grew panicky. "Let me down," he cried, *"let me down!"*

In later years, when Wilbur had become an expert pilot, he recalled this episode with a smile. The "appalling" altitude to which he had been lifted from the ground in his first flight was eight feet.

IV

THE WRIGHT BROTHERS had now proved that man could *glide* through the air. But the more important question still remained unanswered. Could man *fly* through the air? For three years they experimented with motors and propellers in an effort to supply the answer. Years of hard work and continual disappointment. At one time Wilbur was so discouraged that he was ready to give up. "Not in a thousand years will man ever learn to fly."

But Orville, the younger and the more daring of the two, kept urging his brother to go on. New wind tunnels, new airplane models with wings of various edges and curvatures, and tables upon tables of calculations and resultant figures for their subsequent tests. "Will you boys ever stop working?" asked their father, with a skeptical smile.

"Not until we have built a machine that can fly," replied Wilbur.

"And *that,*" rejoined Orville," will be only the *beginning* of our work."

See them now at their work in the back yard of their bicycle shop. Wilbur, thirty-six years old, tall and rangy, face closely shaved, firm thin lips, muscles of steel, and a steel-like glint of determination in his gray-blue eyes. Orville, thirty-two, shorter and more compact, with a heavy dark mustache that conceals the firmness of the upper lip, but with the same determined gray-blue glint in his eyes. Two dynamic machine men, their feet planted upon the ground, their hearts uplifted toward the skies.

And at last their heart's desire seemed about to be fulfilled. Toward the end of 1903 they had finished their first motorplane—the result of several years of theoretical calculations. They took it to Kitty Hawk for its practical test in the air.

But just then they received bad news. The scientific world had come to the "final conclusion" that flight in heavier-than-air

machines was impossible. Professor Langley of the Smithsonian Institution had built, with the aid of government funds, an intricate and costly airplane. An imposing group of scientists had gathered on the banks of the Potomac to watch its initial flight. But it refused to fly. The dream of the ages, agreed the scientists, must remain an unattainable dream.

It was under these discouraging conditions that Wilbur and Orville prepared to make their first attempt with their modest little "air toy." Like the Langley machine, it was equipped with propellers and a motor. But unlike the Langley machine—and this was a secret which the Wright brothers were keeping to themselves—it was built upon an entirely new principle. As a result of their persistent experimentation, the two unschooled but observant young mechanics had at last discovered the true principles of air pressure—that the pressure of air directed against the under surfaces of the wings and the vacuum created above the upper surfaces caused the "lift" of the airplane and determined its ability to fly, if driven at a rapid enough speed. Their airplane, crude and inexpensive as it was, had been designed in accordance with these newly discovered principles. Theoretically, it ought to work. But *would* it? What business had they, a couple of bungling tinkers who hadn't even had a college education, to set themselves up against the scientific verdict of the greatest contemporary scholars? And so it was with a mingled feeling of hope and misgiving that they got ready for their take-off.

Monday, December 14, 1903. The two brothers toss a coin for the opportunity to make the first test. Wilbur wins the toss.

The test results in complete failure. The plane, after staying in the air for three and a half seconds, topples sideways to the ground.

Two days of repairing the broken parts, and the Wrights are ready for the next attempt. It is now Orville's turn.

December 17. The day is overcast. A raw northeaster blows in from the Atlantic half a mile away. The two pioneer airmen,

their blood thinned from too much confinement in the bicycle shop, are stamping their feet and flapping their arms to keep themselves warm. They wear no overcoats, for an overcoat would hamper their movements in this dangerous experiment. As they prepare their clumsy mechanical bird for its tentative flight, they observe a flock of sea gulls soaring gracefully overhead. A raucous shriek from the gulls, as if in mocking challenge to the men below. The brothers are practically alone on the dunes. Only five spectators have taken the trouble to come from the near-by village. One of them looks from the birds to the plane and remarks with a sneer. "*So that* rigamajig is a-goin' to fly?" "Sure it is," rejoins another of the spectators, "in a hundred-mile tornado!"

The brothers, paying no attention to the jeering remarks, tune up the motor. With a roar that drowns out the beating of the surf, the engine begins to spit fire and smoke from the open exhaust. Orville climbs into the wings. "Let her go!"

A moment of breathless expectation—the moment for which a hundred million years had been waiting. Orville grasped the controls—and then the miracle happened. The first mechanical airship began its historic flight.

V

A YOUNG REPORTER, H. P. Moore of the Norfolk *Virginian-Pilot,* heard about the flight and set his imagination to work. He prepared a wholly fictitious story about a "long journey" through the air, at the end of which the operator of the machine ran over the ground yelling "Eureka." He sent the story to twenty-one newspapers, only three of which took the trouble to print it. When Orville learned of this incredulity on the part of the editors, he merely shrugged his shoulders and laughed. "No wonder they disbelieved the story. It was an amazing piece of work. And yet, though 99 per cent wrong, it did contain one correct fact. There *had* been a flight."

But neither the editors nor the public would recognize this fact. "A couple of silly boys bucking against the eternal laws of nature." Some of their Dayton acquaintances were even sarcastic about it. "Flying and perpetual motion will come at the same time," sneered one of them. And another, "There is only one thing that could lift a machine off the ground—spirit power. And the Wright boys are not even spiritualists."

No, the Wright boys were just a couple of mischievous pranksters, especially Orville. He had a habit of storming up the steps to his bedroom on all fours, like a child. It didn't bother him or Wilbur that the world looked skeptically upon their work. Their invention was a fascinating game, nothing more. Even in after years, when the world had come to recognize their work, they refused to be puffed up. They had merely "pulled off" a good play in their game. They retained their good-natured modesty when colleges showered them with honorary degrees and kings favored them with their smiles. They came both to the college presidents and to the kings dressed in their ordinary street clothes and their caps.

They felt no pompous awe in the presence of royalty and they expected the public to feel no pompous adulation in their own presence. Again and again they refused to make public speeches. "I know of only one bird, the parrot, that talks," said Wilbur, "and the parrot can't fly very high." They were careless about the medals and the ribbons which they received from scientific societies. They carried them around, together with other commonplace doodads like screws and bolts and scraps of paper, in their pockets. And they felt more chagrined when they mislaid a bolt than when they lost a medal. They possessed, in other words, the simplicity of greatness.

They never married. Their sister Katharine, who taught at the local high school, provided them with all the feminine companionship that they needed. Together with their old clergyman-father, they enjoyed that most perfect of human relationships—a harmonious family.

But suddenly the harmony was shattered. One May 30, 1912, Wilbur died of typhoid fever. He was only forty-five at the time, and his death meant the ending of one of the greatest inventive partnerships in history. Throughout their work the two Wright brothers supplemented each other. Together, they formed one supreme intellect. But apart, neither of them could accomplish much. In spite of his genius, Orville felt physically and mentally lost without his brother. And he never found himself. The invention of the airplane had come out of the interplay of their ideas. It was like a spark generated by the clashing of two swords. And when one of the two swords lay broken, the other remained inactive in its sheath. For a little while after his brother's death Orville tried to go on. He experimented and made improvements on the stability of the airplane. But his heart was no longer in the work. With the passing of Wilbur, Orville had grown from a boy into a man. Aviation had ceased to be a game for him. It was now a business. And Orville hated business. After three years as president of the Wright Company, he resigned.

VI

On December 17, 1928, the United States celebrated the twenty-fifth anniversary of human flight. A monument had been erected at Kitty Hawk in honor of the Wright brothers. Orville had been invited as the principal guest. He stood beside the monument and smiled sadly at the cheering crowd. "Mighty eagle of the air!" they called him. But it was a broken eagle that stood there, with his frail gray head uncovered to the sky. His eyes roamed over the sand dunes. Drifting sands—drifting years. Past landmarks obliterated—past friendships buried. He felt suddenly cold and alone in the great crowd. His mind went back to the Ohio graveyard, where his brother lay cold and alone. Two brave eagles, equally indifferent to the jeers and the cheers of the world.

LEE DE FOREST

Important Dates in the Life of Lee De Forest

1873—Born, Council Bluffs, Iowa.

1896—Graduated from the Sheffield Scientific School, Yale.

1902—Chosen vice-president of the American De Forest Wireless Telegraph Company.

1906—Resigned from company.

1907—Invented the three electrode thermionic vacuum tube.

1910—Arranged for broadcast from the Metropolitan Opera House, the first broadcast of opera in history.

1912—Developed Audion into an amplifier.

1915—Human voice first broadcast across Atlantic by means of the vacuum tube.

1921—Developed apparatus for talking pictures.

1924—Produced the first sound newsreel of President Coolidge on White House lawn.

1934—Entered business to manufacture diathermy machines.

1943—Devised a terrain altimeter to aid war pilots in "blind flying."

Lee De Forest

1873–

LEE DE FOREST'S career as an inventor is an extraordinary study in frustration. His inventions which formed the core for multimillion dollar businesses should have made him wealthy. Instead they drove him into bankruptcy. He was the father of radio, yet not a branch of the industry bears his name. He pioneered in talking pictures, and the profits went to others. He was almost sent to jail for prophesying that the human voice would one day be broadcast over the Atlantic. Two years after he was indicted for soliciting public money for such a "fraudulent" purpose, the human voice was actually transmitted over the Atlantic from America to Paris. He had a genius for playing hooky whenever the laurels of success were handed out in the classroom of competition. He was the hero of an Horatio Alger story turned topsy-turvy.

From his earliest he was on the frosty outside looking in through the windows at the cozy elect. He was the son of missionaries who followed the "call," and who, in their religious fervor, compelled their families to partake of their hardships. His mother, whose ancestors migrated to the frontiers of Iowa as members of a mis-

sionary band, met his father while she sang in the choir of a congregation over which he presided in Council Bluffs. They married and lived a life of mutual sacrifice seasoned with common zeal.

The germs of martyrdom were endemic in Dr. De Forest. When an offer was made him to leave his relatively comfortable position in Council Bluffs, and accept a job to direct a Negro College in Talladega, Alabama, the thick of the black belt, during the stormiest years of Reconstruction, he accepted with zest.

He took up his abode among the Negroes, moving his family into the college dormitory, and he rationed the pleasures of his offspring with severity. When the circus came to town, he forbade Lee to visit the "Big Tent," for that would be setting a "frivolous example" for the Negro children of the community. "There was nothing spiritual about the Circus."

Talladega was an impoverished town lacking all the material joys for which children seek. There were no Christmas toys in the shops. No firecrackers for the Fourth of July. Yet this very lack proved to be a blessing. Lee had to make the things he wanted. Never was it truer than in Lee De Forest's case that necessity was the mother of invention.

When he was only a child, he was exposed to a personality-shaping experience. His father took him to an exhibition of Thomas Edison's recently-invented phonograph. When the crank was turned and a human voice emerged from the weirdly constructed box, Lee was hysterical with excitement. Hours after he returned home he refused to be quiet. He turned and tossed so feverishly in his bed that night that his mother brought him medicine for his stomach.

The spell of the phonograph was not transitory. All clever mechanisms affected him, even the pictures of them. He spent many hours poring over his father's encyclopedia at the mechanical wonders of the world. His passion for construction took the most poetical turns. After reading the story of King Arthur, he

turned his bedroom into the chapel of a medieval castle and kept a vigil at an altar.

As Lee grew in years, some of his inventions were whimsical, even extravagant. With the ardor of a teen-age talent, he drew numerous plans for a perpetual motion machine. He sketched the model of a "prayer-recorder," a "talking device" which would free a religious person from offering up the same devotion each morning. (This, from the son of a minister!) He tinkered to turn each fancy into some kind of a gadget, to pry open every dream with a tool.

His father was far from impressed with his inventions. Having originally assumed that his son would follow in the ministry, he was startled by Lee's declaration that he desired to major in electricity not divinity. Dr. De Forest yielded to his son only after prolonged resistance. Reluctantly he sent him off to a preparatory academy at Mt. Herman, Mass., from which, at the age of twenty, he entered the Sheffield School of Science at Yale.

But Lee, in declining to follow the calling of his father, had avoided one martyrdom merely to stumble into another.

II

GANGLY, sunken-eyed, bushy-headed, he was easily the "homeliest freshman at Yale." His meager surroundings at Talladega had not prepared him for the fastidiousness of society. Uncouth and perpetually hungry, he gorged himself on the refreshments served at the University teas, to the embarrassment of his friends. Since his father was too poor to provide him with an adequate allowance, Lee couldn't afford to spend more than twenty cents for a meal. The pangs of hunger cramped his energy for study.

While Lee was in his senior year at Yale, Dr. De Forest died suddenly, leaving his wife penniless. She came to New Haven and opened a rooming house on "Freshmen's Row." Lee fruitlessly put his talents to work to break the chain of poverty. And schem-

ing for money, he came upon a special kind of dream—a dream which was eventually to give billions of dollars to others and heartaches and immortality to himself. In his studies at Yale, he came upon a mysterious force that had already fascinated farseeing physicists in Europe and which was destined to open up a new era in civilization—wireless!

The story of wireless is one of the most dramatic in the annals of science. In 1887, Heinrich Hertz, a German professor, formulated the presence of electro-magnetic waves that miraculously followed the curvature of the earth. Some advanced minds immediately grasped that these waves might be used to send and receive messages. As early as 1896, Sir William Crookes, the British physicist, boldy envisaged the day when, "Any two people living within the radius of sensitivity of . . . receiving instruments . . . could . . . communicate as long and as often as they wished by timing the impulses to produce long and short waves on the ordinary Morse Code."

The same year that Crookes made his declaration, a twenty-two-year-old Italian, Marconi, had actually succeeded in telegraphing signals over short distances *without wires.*

Several thousand miles away in America, a young Yale student was equally fascinated by the potentialities of the electro-magnetic waves. Lee De Forest heard a thrilling lecture delivered by one of his professors on these waves, and he came away with the intention of devoting his life to them. He didn't know it at the time, of course, but in entering the field of wireless, he was fated to pioneer in something far greater than the special branch of wireless telegraphy. He was to become a founding father of the modern science of electronics.

So far as immediate material success was concerned, he couldn't have chosen a thornier path. There were not a half dozen men in America at this time who understood wireless. Not a single university was adequately equipped for experiments in electro-magnetic waves. Not a single commercial laboratory had room or

a salary for a fanatic who tinkered with "sending messages through space." To enter a field considered the domain of "crackpots" by the men who controlled American capital was practically to commit occupational suicide.

Yet Lee De Forest left Yale with a Ph.D., determined to surmount the narrow-mindedness of his contemporaries.

III

He came to Chicago, tramped the streets and finally obtained a job in the dynamo factory of the Western Electric Company, performing conventional work in electricity. Within a short while he was transferred to the telephone department where he was assigned the duty of wiring switchboards. His superiors were impressed with his efficiency. And he summoned up enough courage to ask them if he might use the company's laboratory for experiments he wished to make in wireless. They received his request with a puzzled expression. But they granted him permission, at the same time warning him that these experiments must not interfere with the job for which he had been hired.

Lee was resourceful. He snatched time from his lunch hours and spent his evenings tinkering with his equipment. After thorough study he had come to the conclusion that the weak link in the wireless system Marconi had introduced into Europe was his device for picking these messages out of the ether. The Marconi wireless detector was a rather crude tube filled with metal filings which clung together to form a circuit at the receipt of a signal. Before another signal could be admitted, these filings had to be tapped loose with a hammer. The process was slow and cumbersome at best.

De Forest, believing he could improve the system, worked on an invention of his own. He called it "Sponder." It was an automatic self-restoring detector which utilized a telephone receiver for the detection of the signals. De Forest had hit upon an idea

for speeding up the entire process of sending and receiving messages.

So absorbed was he in the development of the "Sponder," that he spent more and more time away from his telephone work. Just when his superiors were on the point of giving a drastic demonstration of their annoyance, he was presented with an opportunity to leave the job altogether.

An inventor from Milwaukee, who had only recently become fascinated with wireless telegraphy, had gotten wind of De Forest's experiments. This Mr. Johnson came down to Chicago and offered De Forest a position as chief engineer in his laboratory at fifteen dollars a week.

But the job was short-lived. Johnson had developed a wireless detector of his own. When he discovered that De Forest had been working on a detector he asked to examine it. But the young inventor for once in his career took a business-like stand. He refused to reveal to Johnson the secret of his mechanism. "This is my invention," he explained. "I suspect that it may revolutionize wireless. I have no intention of putting it into the hands of any company until that company is mine alone." Johnson replied to this audacity by showing his assistant the door.

Back went De Forest to Chicago to look for another job to tide him over further experiments with his invention. Above all he needed laboratory space. Learning that the Armour Institute was hunting for an instructor, he made a deal with the director to teach classes in physics three hours a week free of charge, in return for the use of the Institute's electrical laboratory. In addition, he took a part-time job on a scientific journal for ten dollars a week. Eventually the "Sponder" absorbed so much of his attention that he persuaded the editor to reduce his job—and, of course, his pay—to half time.

He was so poor that he went about his room barefoot to spare the leather of his shoes. And he stood up so that his trousers would last longer. His only recreation was music—divine music. For

twenty-five cents, he climbed up into the gallery of the best concert halls to hear the symphonies of Beethoven, the operas of Richard Wagner. Someday this music would come over the air waves into the homes of millions of people because a gaunt young man in the gallery was willing to suffer limitless privations for an idea.

Finally in the summer of 1901, the "Sponder"—or the electrolytic anti-coherer, to designate it more scientifically—passed its final tests. All that was necessary was to induce backers to put money up for its industrial manufacture.

An international yacht race was scheduled to be held off Sandy Hook, New York. De Forest signed a contract with a press association to report the event by wireless telegraphy. He reasoned that in bringing his invention to the public in such a dramatic fashion, he would inevitably attract a commercial sponsor. On the day of the race he reported to the starting line in a tug, prepared to wire his reports to a receiving station established near the Sandy Hook Light House. In a sister tug, a few yards from his own, the Marconi interests, engaged to report the event for a rival press association, were checking their apparatus, prepared to use their own specially patented system.

The situation was dramatic. Here was an opportunity for De Forest to demonstrate the superiority of his "Sponder" before thousands of spectators; to beat the lion of wireless at his own game.

The race had hardly begun when De Forest noticed with consternation that the flags of the land station signaled ominous news. The wireless was not being received clearly! In a short while, however, the flags ceased signaling and DeForest breathed a sigh of relief. His sense of security would have been short-lived if he had known what had actually happened. The reports from the rival tugs had jammed one another. Both Marconi and De Forest had violated the principles of tuning. It had occurred to neither

of them to provide different frequencies for transmissions through the ether.

Despite this fiasco De Forest persevered in his efforts to "sell" his wireless. After several disheartening attempts to form a company, he met with an individual who was destined to play a diabolical role in his life. This chap was a speculator. During the gold crisis when the Cleveland Administration offered to sell bonds to the highest bidder in gold, he had won a bid for several million dollars worth of bonds without a cent in his pockets. Then, with stupendous nerve, he had gone to the wealthy Russell Sage and persuaded him to "put up" the gold.

This extraordinary promoter took a fancy to De Forest's system of telegraphy, and he immediately went to work to raise money for it. As a result, the American De Forest Wireless Telegraphy Company was organized with an authorized capital stock issue of three million dollars. The promoter became president of the company; De Forest, the vice-president.

Now we pass to an incredible phase of De Forest's career; one utterly in keeping with his genius for ill-luck. Rapidly he sky-rocketed to fame. Once his wireless became publicized, United States military circles became interested. The Army commissioned De Forest to install test equipment for the Signal Corps. The Navy, too, enthusiastic over a wireless demonstration during fleet maneuvers, equipped the vessels of "Fighting Bob Evans," a celebrated admiral of the day, with De Forest sets.

The general public also responded to the new wireless telegraphy. At the invitation of the British Government, De Forest installed communication between Wales and Ireland. He despatched an operator to Shantung, China, to report the Russian-Japanese naval war. Then in 1905 the blow fell.

Returning from Europe, he discovered that certain of his business associates had gained control of the majority stock of the company. They seized upon the opportunity afforded by a dispute over one of his patents to tell the man who had established wire-

less in America that the company no longer had need of his services.

And De Forest, one of the world's worst businessmen, asked as the price of his withdrawal from his company the sum of only a thousand dollars! And he didn't even receive this amount. When he came to collect the money from the attorney whom he had hired to settle the final papers, the lawyer handed him five hundreds dollars and dryly told him that he was keeping the remainder as his fee.

Between his lawyer and his company, De Forest had been stripped of practically all of his material assets. All but one. Bereft of the rights to his "profitable" wireless which had been retained by the company, De Forest walked out of the lawyer's office with a scrap of paper bearing the rough plans for a new device with which he had been tinkering in his spare moments. His sharp associates, deeming it worthless, hadn't bothered to deprive him of the patent. They lived to regret their shortsightedness.

They had taken everything from De Forest but the rights to six billion dollars. For this scrap of paper contained a design which developed into one of the great inventions of the twentieth century—the radio vacuum tube! Eased out of the field of wireless telegraphy, De Forest went home to his laboratory and made radio possible.

IV

For several years De Forest had been experimenting with the idea of the little device which was to revolutionize an era. Back in 1903 while perfecting his "Sponder," he had chanced upon a peculiar phenomenon. When he sparked the coil of his "Sponder," he noticed that the gaslight in his room grew dim. When he cut the coil, the light immediately became brighter. Fascinated by the reaction, he removed his "Sponder" to another

room and shut the door. This time the phenomenon did not take place. It seemed obvious that the sound of the spark had caused the response in the Welsbach gas mantle.

Immediately he speculated on the significance of this occurrence. Perhaps this gas flame pointed to an infinitely more sensitive method of detecting electro-magnetic waves than any yet established.

Alerted by his experience with the Welsbach gas mantle, De Forest now searched for a method of treating the flame that would render it sufficiently conductive to a voltage effective for a wireless detector. He tried alkaline salts and metals but failed to increase the conductivity appreciably.

Next he turned his attention to the incandescent lamp, by means of which Edison had turned electricity into light. This Edison bulb De Forest knew was an amazing source of electro-magnetic waves of ultra violet and heat radiation. Edison in his experiments had observed one peculiar phenomenon that took place in his bulb. When the plate separated from the filament by a narrow gap was charged positively, a tiny stream of energy shot over the gap and set up a circuit.

The thought struck De Forest that this Edison lamp might be used to *generate* waves of any length by the addition of a piece of platinum wire twisted into a shape resembling a grid. He would place it between the filament and the plate in such a way as to control the electric current between the two.

And by as startlingly simple an innovation as this piece of twisted wire, De Forest made history. The complete significance of this wire was not even grasped by De Forest at this time. The tiny stream of energy Edison had observed in his lamp leaping from the positively charged plate to the filament—an occurrence known as the "Edison reaction"—was nothing less than the release of electrons.

By inserting his grid electrode, De Forest had provided a handle for the control of the electron. He had placed stupendous

energy into the hands of man. De Forest's "three electrode thermionic vacuum tube," as his device was called, had become the basis for the electronics industry whose magic is just beginning to be felt today.

In 1907 when he invented the tube, the nature of the electron was not fully understood. He conceived of his Audion, as he referred to the tube, merely as a detector of electro-magnetic waves. He used the Audion daily without realizing its potential significance as an *amplifier* of these waves.

Only in 1912, five years later, during further experiments, did he make the discovery that his tube had the power to do for sound what the microscope has done for sight. It could amplify a noise until a whisper might be heard around the world; and the dripping of water could be turned into a symphony.

Here was the missing link in the evolution of wireless. Long distance telephoning was hereby made possible. Here, too, was the means for radio.

Indeed, the vacuum tube is the very heart of radio. By adding tube upon tube, long-distance voice currents too feeble to be detected by ordinary means could be relayed, regenerated by continuous waves, so that they would not die.

In addition to revolutionizing wireless, this magic tube in time has fathered radar which guides ships and planes through storms. It spawned the photoelectric cell which measures cosmic rays, sends pictures by wire, sorts merchandise. It became responsible, among other things, for controlling printing presses, running phonographs, ferreting out hidden minerals and oil, detecting growths in the human body, conditioning air, bombarding the atom, cooking meats, vulcanizing tires, and for a world of additional electronic marvels. In fact, there seems to be no limit to its miracles.

By December 31, 1906, De Forest had reached a stage in his investigations with the Audion at which he was able to transmit human speech across his laboratory. By 1909 he was transmitting

phonograph music over the air waves to friends several blocks away. His private audience had arranged to wave him signals reporting the results of the "reception." And passers-by on the street below were frequently startled upon looking up to discover a man leaning out of a window of a respectable-looking office building and waving a towel feverishly in the air.

During one of these experiments in the absolutely unprecedented art of "broadcasting," a slightly inebriated wireless operator in the Brooklyn Navy Yard suddenly heard curious words and music coming over his ear phones instead of the usual dots and dashes of the Morse Code. Thinking he had drunk himself to the point of delirium, he called his superior in consternation and handed him the phones. Sweat stood out on the boss's forehead as he "listened in" to the unbelievable sounds. Neither man realized it, but they had tuned in by accident upon one of De Forest's "broadcasts." History selected them as a pioneer radio audience!

Continuing with his transmissions—the term "broadcasting" did not come into use until many years later—De Forest invited a celebrated vocalist of the Manhattan Opera Company, Madame Mazarine, to sing into his microphone to a specially selected audience of friends who "listened in" from a downtown building. De Forest then persuaded the management of the Metropolitan Opera to participate in a unique experiment—the transmission of an entire program of opera. He installed two microphones on the stage of the opera house and another in the wings. A half-kilowatt transmitter was set up in an empty room at the top of the house. A crude antenna hung from two bamboo fishing poles. Several audiences were invited to "tune in" on the opera. One group was stationed in De Forest's laboratory, another in the Metropolitan Life Insurance Building, a third in one of the downtown hotels.

For the transmission, the Metropolitan selected a traditional menu—the twin operas *Pagliacci* and *Cavalleria Rusticana*.

Caruso sang in a starring role. And his magnificent voice was received over the air waves with enthusiasm.

The date of this history-making broadcast, realized through the genius of De Forest, was January 20, 1910. Yet the inventor still faced years of struggle before the commercial interests of America finally woke up to the fact of radio and made it a regular part of the national life. De Forest was a decade ahead of his times.

For ten long years De Forest remained the lone broadcaster in the world! And a group of young men, enkindled by his vision, rallied around him, championing his cause. They were the radio "hams." Scattered over the country, working for the sheer love of the sport, they tinkered with strange receiving sets, and put on earphones to pick messages out of the ether while their unimaginative neighbors looked on with astonishment.

But the general public failed to appreciate De Forest's pioneering efforts. As for the Government, it heaped an incredible insult upon him. It tried to send him to jail!

He had been "rash enough" to declare in a newspaper interview that the human voice could be transmitted across the Atlantic Ocean by means of his vacuum tube. And to accomplish this feat he had sold stock to the public for the commercial manufacture of the invention.

A United States marshal pounced upon him and placed him under arrest. The Government charged him with using the mails to defraud the people. On November 12, 1913, he was placed on trial with several associates in New York. The District Attorney, holding up the vacuum tube before the jury, declared dramatically that, for selling stock in "this worthless piece of glass," De Forest should be sentenced to the penitentiary! Fortunately, however, the jury did not follow the advice of the District Attorney. It had the good sense to acquit De Forest of fraud. Nevertheless, the experience left him shaken.

In October 1915, two years after his indictment by the United

States Government, the public received the epochal news that the human voice had been successfully transmitted from Arlington across the Atlantic to the Eiffel Tower and half way across the Pacific to Honolulu. De Forest's "criminal" prophecy had been realized.

But he was no longer in a position to take advantage of it. He had met with such financial discouragement that he had been compelled to sell his patent to the American Telephone & Telegraph Company for fifty thousand dollars. And it was the latter that had accomplished what he had dreamed of doing himself.

Four years later, in 1919, "big business" finally "discovered" the entertainment value of radio. Commercial broadcasting commenced. Huge corporations entered the field, and ripe fortunes were garnered.

But De Forest failed to share in the bonanza of the industry he had helped to create. He severed his connection from radio as he had done in the case of wireless fifteen years previously. And he entered a laboratory in Germany to undertake investigations which led to the development of a new industry.

V

As EARLY AS 1913 De Forest had conceived a plan for transforming the silent movies into talking pictures with the use of his Audion. Retired from the field of radio, he gave his entire time to pioneering in the new field of movie sound, years before it became a commercial fact. "To pioneer has always been an obsession with me."

In 1921, working energetically in his German laboratory, he perfected a mechanism which he called "Phonofilm." The principle is basically the one applied today. "I have . . . photographed the voice onto an ordinary film. The sound is printed on a narrow strip along the side of the pictures."

Returning to New York, he found himself faced with the same

pattern of struggle he had experienced in trying to "sell" radio. From 1923 until 1927, he tried to interest the leading Hollywood producers in "Phonofilm." In vain. They came politely to his demonstrations and left his laboratory unimpressed. They refused to invest a penny in "talkies."

And so he went ahead with his own plans. He spent his diminishing resources making sound shorts himself. In 1924 he produced the first sound newsreel, photographing President Coolidge on the lawn of the White House. In 1925 he invited Al Smith and Theodore Roosevelt, Jr., to his studio to appear in a film during their race for the governorship. In addition, he issued feature shorts of some of the leading stars of the times, George Jessel, Eddie Cantor, Weber and Fields, and orchestra recordings by Ben Bernie and Roger Wolf Kahn. He was his own director, stage manager, sound engineer. And he actually succeeded in selling his "Phonofilm" equipment to more than thirty theaters.

But, as usual, evil fortune dogged him. In 1926 Warner Brothers became the first major studio to take the plunge into talking pictures. But they invested in a method that differed from De Forest's. They produced talking pictures by synchronizing phonograph recordings with the film. Eventually, however, they and all the other major studios resorted to the process De Forest had advocated since 1918—the sound photographed on the strip of film.

Fox was the second large studio to enter the field of "talkies." However it bought the rights not to De Forest's "Phonofilm" but to a system devised by a young man who had worked several years with De Forest, and who had parted from him as the result of a quarrel. De Forest simply wasn't on speaking terms with success.

The final irony was yet to come. Heavily in debt as the result of his financial misadventures, plucked dry of huge sums of money in prolonged legal litigation over his numerous patents, De Forest finally went "broke." In 1933 the very year New York's Radio City was completed, the man who was largely responsible for

radio was looking for a job! And three years later De Forest was forced into bankruptcy. He listed his debts at more than three hundred thousand dollars against three hundred and ninety dollars in assets!

Two friends came to his aid with a small investment. As a result De Forest bought a little shop in Hollywood, California, and began to manufacture diathermy machines. Gradually he developed a prosperous little business. He simply refused to be driven against the ropes by the punches of a malevolent destiny.

Here is the compelling story of an American inventor who in his seventies retains his buoyant optimism. His career seems to have been a perversion of the classic Cinderella theme. And yet De Forest is a happy man. He has drawn solid satisfaction from his work. He has lived to witness his wildest prophecies realized, to know that vast numbers of Americans are employed in jobs his genius has created.

Above all he owns what can never be deducted from his account—a name for the ages.

LEO HENDRIK BAEKELAND

Important Dates in the Life of Leo Hendrik Baekeland

1863—Born, Ghent, Belgium.

1886—Became an associate professor at the University of Ghent.

1889—Arrived in the United States. Entered field of industrial chemistry.

1893—Organized the Nepera Chemical Company for the manufacture of "Velox" paper.

1899—Sold business to the Eastman Kodak Company.

1906—Commenced research in resins.

1909—Announced his discovery of Bakelite.

1910–39—Served as president of the Bakelite Corporation.

1944—Died, Beacon, N.Y.

Leo Hendrik Baekeland

1863–1944

In Yonkers, New York, during the early decade of this century, a middle-aged, bearded fellow puttered around in a chemistry laboratory at the rear of his estate. His neighbors, holding their noses as they passed this laboratory, speculated over what new miracle "Doc" Baekeland could be conjuring in his test tubes. The "Doc" possessed a reputation for wresting secrets from the weird interplay of chemicals. He had already made a fortune from a newly-processed photographic paper. And, it was rumored, he had done remarkable work in electrolytics.

So wagged the tongues. Night after night the lights of the laboratory burned brightly. Finally the battle of the test tubes ended. And the neighbors learned one morning from the newspapers that Dr. Baekeland, while on a search for a substitute for shellac, had opened the gates to a magic new industry—plastics!

II

"My real education began only after I left the university," Leo Hendrik Baekeland was fond of declaring. "I hope to remain until

I die, a postgraduate student in the greater school of practical life, which has no fixed curriculum and where no academic degrees are conferred, but where wrong, petty theories are best cured by hard knocks." Baekeland, although he won his full share of academic degrees, was a highly creative student who refused to be chained to a "fixed curriculum."

Born in the Flemish city of Ghent, Belgium, in 1863, he never did follow an orthodox routine. As a youngster he dreamed of running away to sea and becoming a sailor. Hence he excelled in his geography lessons and very little else. As he grew older he forgot the sea in a passion for photography. Evenings when his father believed that he was studying his lessons in his bedroom, he was secretly developing pictures he had taken during the day.

His preoccupation with photography led to a more general interest in chemistry. On one occasion he needed a silver nitrate solution, but he had not the money for it. His father, however, had given him a watch with a silver chain. He took off the chain, dissolved it in nitric acid, and worked out a plan to remove the copper from the solution, leaving him with the desired preparation.

In addition to his regular classes at high school, he attended special evening lectures in chemistry at the Ghent Municipal Technical School. And he astonished his teachers with his brilliant grasp of the subject. There was no doubt that this youngster had the makings of a modern alchemist in whose fingers lay the skill for mixing new substances out of the elements.

At seventeen Baekeland entered the University of Ghent on a scholarship. He was the youngest member of his class. Within four years—at twenty-one—he received his Doctorate of Science. And at twenty-six, after teaching for a period in a normal school, he became an associate professor at his Alma Mater. A chief motive for returning to Ghent as a professor had nothing to do with teaching. He had fallen in love with pretty Celine Swarts, the daughter of his old chemistry instructor. Upon his appoint-

ment to the faculty, he married Celine. The couple led an ideally happy existence.

The course of Baekeland's life seemed set. Like other brilliant students, he had been absorbed by the teaching profession. It appeared as if he would end his days as a quietly efficient pedagogue. So rapt was he in his scientific problems as he walked to and from his laboratory, that he remained unaware of the very ground before him.

Years later after he had settled in America, a colleague called upon him for a contribution to rebuild the carillon of the library at Louvain which had been shattered during the First World War. As Baekeland wrote his check, he reminisced over the bells of his native Ghent which had disturbed him as he labored in his laboratory. "There were too many bells," he grunted good-naturedly. "They were going all the time whenever I tried to work."

Events, however, had rescued Baekeland from the bells. While still a member of the faculty, he won a traveling fellowship in a competition held for the alumni of the four leading universities in Belgium. He traveled to England, Germany and Scotland, studying for a time at Oxford, University College and the University of Edinburgh. Then, still on leave from the faculty, he sailed for the United States to conduct researches in the chemistry of photography. Ghent was a center for the manufacture of photographic dry plates. And the leader of the industry, Dr. Van Monchoven, had taken an interest in Baekeland and had encouraged him to undertake experiments in this important industrial field.

Upon his arrival in the United States, Baekeland met several people who influenced him further along these lines. Richard A. Anthony, a member of a firm that manufactured photographic materials, and C. F. Chandler, a professor of chemistry at Columbia University and a consultant of the firm, induced the young Belgian to turn aside from his academic career and bring his talents to American industry.

Baekeland cabled his resignation from the faculty of Ghent University to the Belgian Minister of Education. The die was cast. Belgium lost a professor, and the United States gained one of its foremost pioneers in industrial chemistry.

III

BUT FOR A TYPE of scientist who is fascinated less by broad theoretical principles than by workable results, there would be little development of industry. The Einsteins wrestle with the stars. The Baekelands step into the factory and make the practical world a better place to live in. Both types of thinkers are vitally necessary.

Upon settling in the United States, Baekeland accepted a position as chemist with the Anthony Company, manufacturers of photographic equipment. But he was ambitious. Within a couple of years he resigned and became a research chemist on his own.

He suffered from the embarrassment of a rich imagination. Not as yet having learned the lesson of concentration, he embarked upon several projects at once. "I tried to work out several inventions, the development of which would have required a small fortune." He dabbled with a process for extracting tin. But while testing under hazardous conditions, he suffered an accident which almost brought him "within close acquaintance of the undertaker." This accident robbed him of his zest for carrying out another pet project—an experiment with explosives.

Instead he returned to his old love—photography. And he hit upon the solution to a problem that had fascinated him for years—the development of a new photographic paper. Contemporary processes involved the printing of pictures in the sun. But this was controlled by the vagaries of weather.

Baekeland now succeeded in developing a colloidal silver chloride which was relatively insensitive to the yellow rays of the spectrum. This meant that pictures could be printed regardless of

the weather, a short distance from artificial light, provided they were not held too near the candle or gas flame.

Convinced that Velox paper, as he labeled his invention, would revolutionize photography, Baekeland went into partnership with Leonard Jacobi, a Yonkers businessman, for its manufacture.

Initially, the Nepera Chemical Company—as the firm was called—ran into technical and financial difficulties. Baekeland discovered that hot summer weather ruined the manufacturing process. To eliminate the effects of extreme humidity upon the paper, he devised a system of refrigeration through which the atmosphere was condensed into ice. Then, it was passed as dry air through heated pipes and raised to the proper degree of temperature before it entered the coating machine.

But even after the manufacturing problems had been met, there were financial hurdles to be overcome. The business had been established during the depression of 1893. With the return of prosperity, sales continued to be pitifully low. Few customers could be persuaded to abandon the old-fashioned and unreliable habit of printing in the sun. "I was rather stubborn in my point of view," Baekeland afterwards recalled. "I kept on trying to convince others how much simpler it is to be independent of sunshine."

For his trouble he received letters of abuse. "I am a professional photographer of twenty-five years' experience," wrote one customer. "Your paper is the greatest photographic swindle of the age. You claim your method of printing is several hundred times faster than albumen paper, and here I have kept a print in the printing frame for several hours in the sun, and I can hardly see a faint image."

Baekeland learned to his amazement that these disgruntled customers hadn't even bothered to read the instructions on the Velox package which told them how to print the pictures!

Eventually, however, Velox, due to its undeniable perform-

ance, "caught on." And the business commenced to prosper. By 1899 the Nepera Chemical Company had become so successful, in fact, that Eastman Kodak offered to buy the firm. And very liberal terms were accepted.

There is a story to the effect that Baekeland traveled to Rochester to meet Eastman, determined to take no less than twenty-five thousand dollars. He almost passed out with astonishment when Eastman offered him a million! Whether this be apocryphal or not, Baekeland retired financially well-set. He bought an estate in Yonkers, high above the Hudson. "At thirty-five I found myself in comfortable . . . circumstances, a free man, ready to devote myself again to my favorite studies."

Now he entered upon the happiest period of his life. He converted one of his buildings into a laboratory, and he carried out various projects. He became interested in electro-chemistry. And he visited Germany to take a course in it. He devoted a winter at the Technological Institute of Charlottenburg and returned to Yonkers for additional study in his laboratory.

At about this time an electrolytic cell was invented for the production of caustic soda and chlorine from salt. Baekeland was approached by a Niagara Falls industrialist to investigate the device for its commercial possibilities. He constructed two model cells, perfected their operations under varying conditions and protected the industrialist from errors that might have cost him millions of dollars. Then Baekeland turned to other matters.

While wrestling with a problem, he had time for nothing else. But as soon as he arrived at a satisfactory solution, he lost complete interest in the problem, and he embarked on something new and quite different. Frequently his various investigations were unconnected with one another, were situated, in fact, in widely diverse areas of chemistry. The character of novelty fascinated him. "It was . . . like turning over a new leaf, and this prevented me from becoming too one-sided."

He had saturated himself in photography. He had tamed the

Leo Hendrik Baekeland

John Logie Baird

difficulties of the electrolytic cell. And now he explored still another field of chemistry—the region of resins. And it was during this phase of research that he became world famous.

IV

WHEN BAEKELAND commenced his research in resins in 1906, one of the most widely in use was shellac. Produced by a little red bug, the *laccifer lacca,* a native of southern Asia, shellac formed the constituent of sealing wax, lacquers, varnishes and a variety of household necessities. But in common with other natural resins, it had a low softening point. It became distorted under the pressure of heat.

Realizing the enormous value commercially of finding a more durable substitute for shellac, Baekeland made an exhaustive study of the field. Certain investigations of his predecessors intrigued him. As early as 1871, Adolph Bayer had noted the peculiar reaction of phenols (carbolic family) and the aldehydes upon one another when he attempted the marriage of these "evil-smelling" chemicals.

Whenever these were mingled, inexplicable things occurred. At the application of heat, the mixture boiled, foamed, sizzled with lava-like intensity, spewing forth hot particles. Once the boiling subsided and the spasm was over, a hard, porous, stubborn, gray-colored mass remained. Nothing could be done with it. It couldn't be melted or dissolved by any of the solvents known to chemists. It was impossible to separate it from the test tube. The tube had to be smashed and replaced for a new experiment.

Quite obviously a material that was characterized by such a resistance to heat, weather and time could be a commercial gold mine. The only difficulty with this porous gray mass was that its activity could not be controlled or predicted by its maker. Therefore, it was, for all practical purposes, useless. So Adolph Bayer, in 1871, after trying assiduously to fuse this substance into usable

form, gave up the attempt and turned to other matters. Succeeding chemists followed suit.

Baekeland, too, was baffled by the reaction of the phenol and the aldehydes. He sought to learn the secret of control that had eluded others. Methodically he studied the experiments of his predecessors step by step, in an effort to analyze why they had failed. To reduce the foaming of the reaction under heat, he added tiny quantities of ammonia; he tried caustic soda. He worked patiently to prepare the proper base by which he could spread out the mysterious reaction into different steps and thereby gain control over the process.

Night after night he went to bed exhausted. His assistants argued that he might as well give up the task. But Baekeland shrugged his shoulders and continued with his experiments.

And suddenly a breath-takingly simple notion took hold of him. Curious how all great discoveries hinge upon simple ideas. Just as he had committed a photographers' "heresy" by developing "Velox" in a fashion that violated the established rules, so now in the case of this latest problem he threw orthodoxy "out of the window." "They should have succeeded," he was subsequently to say of the chemists who had failed. "But they *wouldn't.*"

Baekeland's predecessors had written in their notes that heat was the creative agent. But if too much heat were used, the activity of the process was increased to such an extent that control was impossible. Therefore, they warned that heat must be applied in very moderate amounts, about fifty to seventy-five degrees centigrade.

But Baekeland, pursuing a brilliant hunch, decided that his predecessors were entirely wrong. Not less heat, but *more* heat was actually necessary. While more than moderate heat might be fatal to the process in a normal atmosphere, *the pressure of the air* could be increased to make allowances for an increase in heat. In such a case the chemicals could be "baked" in an oven of compressed air at temperatures ranging from a hundred and fifty to

two-hundred degrees centigrade. The pressure would counterbalance the heat.

Following this concept, Baekeland moved forward to complete success. He increased the heat and added alkalies. He put two liquids into his "oven" and brought forth a magic substance—a transparent ambler-like solid. It formed perfectly in the mold. Once it was heated according to Baekeland's formula, it "froze." It would not melt again. It would not dissolve. It was strong beyond all measure. One short piece of this substance an inch thick could sustain a weight of more than three tons. Light, easily-shaped, marvelously tough, a resistor of heat, electricity, acids and changes in climate, this "baked" substance—the founder called it Bakelite—was destined to revolutionize the industry of the world.

V

On the night of February 6, 1909, Baekeland announced his discovery to the Chemists' Club in New York. The following day the press carried the news, explaining to bewildered readers that the technical name of the new substance was "oxybenzyl-methyl-engly-colanhydride."

At first Baekeland estimated that Bakelite would be used by approximately forty industries. His calculation proved a modest one indeed. Today there is scarcely an industrial plant in the world that doesn't employ some form of Bakelite.

Although one plastic—celluloid—had been placed on the market before Baekeland began his experiments with phenol and formaldehyde, it was with the introduction of Bakelite that large-scale manufacture of plastics really commenced. The electrical industry was the first to manifest a demand for Bakelite. It found it a valuable substitute for hard rubber and amber because of its resistance to current. After a series of laboratory tests the Weston Electrical Instrument Company of New Jersey adopted the plastic for its measurement instruments. Other companies followed suit.

Bakelite became responsible not only for the rapid expansion of the electrical industry, but for the mass production of autos and radios as well. It was introduced into handset telephones. It became standard in distributor heads of autos, self-starters, junction boxes, coil parts. It was utilized for the impregnation of brake linings. During the First World War layers of canvas were treated with Bakelite and fashioned into propellers that were too strong to be shattered by bullets.

Bakelite has been introduced into the armatures of dynamos and motors, dials on radio sets, panels, tubes, sockets, mountings, condensers, binding posts, insulators of high tension electric wires, gun turrets, switchboards of battleships. It has been employed for noiseless gears in machinery. The average person cannot spend a day without coming in contact with some form of Bakelite. Hundreds of common goods have been fashioned from it—the polished tops of restaurant tables, billiard balls, transparent fountain pens, cigarette holders, umbrella handles, ash trays, waterproof fabrics, costume jewelry, belt buckles, cane handles, dentures—to mention merely a partial list of items.

For nearly twenty years the Bakelite Corporation, presided over by Dr. Baekeland himself, monopolized the manufacture of this plastic. By 1933, however, more than thirty companies entered the field and produced it under nearly a hundred different trade names. Altogether that year thirty-one million tons were manufactured.

The discovery of Bakelite spurred research into a whole series of other types of plastics. By 1943 the industry had listed more than five thousand different categories of plastics. The interior of a three-room apartment has been almost entirely built with chemicals. During the Second World War more than nine hundred million pounds of synthetic carbon derivatives went into the production of armaments yearly. And it all commenced when a stubborn Belgian hunted a substitute for shellac.

VI

BAEKELAND lived an additional thirty-four years after his discovery. He died in February 1944, at the age of eighty-one.

Invariably when a man develops something new, a host of competitors go to court claiming that the invention was theirs. This was Baekeland's experience. But he had the personality to charm even his rivals. Some of his bitterest disputants afterwards became close friends and intimate collaborators in the Bakelite Corporation.

He received every kind of distinction from the world of science. He gained half a dozen medals. He served as president of the Inventor's Guild, the American Institute of Chemical Engineers, the American Chemical Society. He was named to the post of honorary professor at Columbia University. He was elected to the National Academy of Sciences.

He accepted these tributes modestly. At one banquet held in his behalf, he declared: "You have talked here tonight about my many discoveries. But you haven't mentioned my greatest . . . a discovery I made when I was still a student. That great discovery was a woman who is here with us tonight—my wife."

Mrs. Baekeland was indeed a remarkable person. She had musical talent, and she became well known as a painter in oils. Yet she was intimately concerned with her husband's profession. She kept his records and advised him constantly on business matters. She was his chief assistant.

Baekeland actively directed the fortunes of his company until 1939 when it became merged with the Union Carbide and Carbon Corporation. At that time he was seventy-six.

But for all his energetic work, he found time to relax. He bought an estate at Coconut Grove, Florida, and cultivated lush flowers in his garden, sending them to his friends up North. He was a yachting enthusiast. As early as 1899 he cruised in a gaso-

line launch up the Hudson to the St. Lawrence. In 1912 he purchased a seventy-foot yacht which he christened with the zeal of a chemist, "The Ion." One of Baekeland's guests during a voyage came into the galley and found the pioneer in plastics bending over a stove, frying eggs. Suddenly the launch was rocked by a wave. Baekeland was pitched into a corner with the eggs in his lap. He picked them up and ate them without a grimace.

As a scientist, Baekeland was an unusual personality. He was absorbed in the general affairs of mankind. He was, in fact, not only a chemist, but a writer, a philosopher—a humanist. During his life he found time to write seventy-five papers addressed not only to his professional colleagues, but to the hard-thinking layman as well. In these he assessed the role of the scientist in society.

Baekeland was a sincere believer in the dynamics of the calculated experiment applied to Man. As the chemical solutions in the test tube mingle to produce powerful new solutions, the races of men in their intermingling with one another have an unlimited possibility of development into strong new blends of social well-being. The one solvent necessary to melt ignorance and prejudice is good will. Humanity must shape its conduct according to the rule of the scientific laboratory with its allegiance to truth.

And Baekeland, answering the charge that science was responsible, not for improving society, but for yielding weapons of destruction which only served to make future wars more horrible, declared:

"Do not blame the chemist for what will happen if irresponsible, tactless politicians or writers continue needlessly to arouse the worst feelings in other nations. . . . *War is many ages older than science*. . . . The remedy for war does not lie in stopping chemistry. The greater remedy seems to be more of a . . . religion of deeds, than a . . . religion of words."

JOHN LOGIE BAIRD

Important Dates in the Life of John Logie Baird

1888—Born, Dumbartonshire, Scotland.

1922—Retired from business.

1924—Commenced research in television.

1925—Demonstrated "shadowgraphs" in Selfridge's London Department Store.

1926—Gave world's first demonstration of true television.

1928—Achieved first trans-Atlantic telecast from London to Hartsdale, New York.

1931—Televised the Derby. Visited the United States.

1936—British Broadcasting Corporation inaugurated regular television programs. First television receiving sets sold to the public.

1944—Devised apparatus for television in color. Designed television by means of stereoscopic vision.

1946—Died, Sussex, England.

John Logie Baird

1888–1946

JOHN LOGIE BAIRD, pioneer in television, was a bushy-headed Scotchman who turned to technological research because ill health prevented him from making a business fortune.

Talk of flashing pictures through the ether seemed to Baird's unscientific contemporaries to be more in line with the ravings of a Hindu mystic than the sober thinking of a down-to-earth Scotchman. Yet there was nothing of the visionary about Baird. "No one speaks more hard-headed sense," declared an intimate friend of his.

Television, of course, is not indebted to the genius of any one man. Its present day achievements are the result of many brains harnessing the giant resources and techniques of modern industry. But Baird's influence has been greater than that of any other individual in the development of the medium.

At the time Baird commenced his experiments in the early 1920's, using the equipment of an amateur in an attic, well-financed experts, staffed by research technicians, had been laboring for years to wrest the secret of television. He succeeded where others failed. To readapt what Winston Churchill declared in a

different context: In the realm of scientific invention never perhaps was there achieved so great a triumph for so many with such little means.

The son of a minister in Dumbartonshire, Scotland, Baird grew up with a sickly constitution but a healthy appetite for gadgets. He was negligent about his dress. He rarely combed his huge shock of hair. His clothes looked as if he continually went to bed in them. He was too greatly wrapped in the wonder of mechanics to care about an untied shoelace.

He turned his home into a beehive of engineering activities. He built, for instance, an amateur telephone system that connected the bedrooms of four of his school companions with his own. One of the wires that hung precariously across the street tripped up a coach driver. Under the impression that he had run afoul of the telephone company, the driver sued, only to learn subsequently that the wire belonged to a mischievous lad. The case was dropped. One couldn't collect damages from Huckleberry Finn.

For his next adventure Baird installed in his home an electric light plant. The current was brewed from a crudely constructed dynamo driven by a water-wheel; the accumulators were improvised with jam jars and sheet lead. Thanks to Baird, his family was the first in the locality to enjoy both a private telephone and an electrical system.

Baird then joined a photographer's club. He experimented with various exposures, even taking pictures of himself while asleep in bed.

Logically enough, at seventeen Baird entered the Royal Technical College in Glasgow for courses in electrical engineering. And then he proceeded to Glasgow University to continue his education. But the First World War presented him with other plans.

He left college and attempted to enlist in the army. But he was rejected because of his poor physical condition. Fortunately he possessed some previous industrial experience, and he was offered

—and he accepted—an engineering post with an electrical power company which supplied the shipbuilding yards and munition plants.

When he left his job at the conclusion of the war, determined upon a physically less exacting career than that of a field engineer, he had only ten pounds to his name. But he possessed the immense capital equipment of a shrewd Scotch head, and an irrepressible business imagination. He might have followed in the footsteps of his countryman, Andrew Carnegie, but poor health robbed him of the energy necessary for large-scale business enterprise. As it was, he devised some interesting promotional schemes.

He developed the "Baird Underwear Sock" to be worn under the outer stocking. This sock was medicated in such a way as to keep men's feet cool in the summer and warm in the winter. He followed this with a specially patented boot polish. But just as he began to make money, ill health returned to plague him. Upon his doctor's advice he sold his business and shipped to Trinidad for a vacation. Before he left, however, he made a deal with several British merchants to peddle their goods to the natives.

Upon arriving at Trinidad, he discovered that the island was already overcrowded with British agents hawking merchandise. And so he looked around for other means "to charm the pound." Noticing that huge quantities of fruit went to waste rotting on the island, he decided to initiate a jam and preserves industry. He selected a fruit-growing area sixteen miles from the capital, erected bamboo huts and provided copper vats for the boiling of the jam. Despite the difficulty of working in the jungle, Baird's business was well on its way to success when he took sick with malaria and was compelled to return to London.

Back in England he refused to surrender to hard luck. Noticing that Australian honey was being sold at a strikingly low price, he invested all his capital in it. He packed the honey in small tins and marketed them at nearly twice the cost. Within half a year he earned enough money to buy into an industry which processed

coir fibre dust from coconuts, a valuable fertilizer. Then he turned his attention to the soap industry. He wrapped a package labeled "Speedy Cleaner" in one-pound twin tablets, placing it with grocers and small retainers.

The net result of all this activity was not a million dollars but a nervous breakdown—so complete a breakdown, in fact, that Baird's physicians warned him to give up business for good.

And so, deprived at thirty-four of the chance to amass a business fortune, he returned, while convalescing, to his old hobby. He commenced to tinker with mechanical gadgets. And he became one of the world's great inventors.

II

Even during his business activity Baird had speculated with the possibility of developing an apparatus for sending an image of the human face through the ether. Television.

The word television is a hybrid derived from the Latin *video,* "I see," and the Greek *tele,* "at a distance." For years scientists had been certain of the theoretical possibility of television. Just as the human voice had been translated successfully into electric current variations and transmitted over long distances, so it was believed that the rays of light reflected from a human face could be changed into electrical impulses, amplified and radiated from a broadcasting station to a receiving post.

The problem was to devise an instrument which would perform in television the role of the microphone in radio; to perfect an "electric eye" sensitive enough to "pick up" the image to be signaled along the wave lengths.

In 1888 the German professor, Heinrich Hertz, had embarked on a project of research which led eventually to the development of a kind of photoelectric cell. It seemed at first as if this would perform the trick of changing light into electric signals. But further investigation revealed that the cells were too insensi-

tive to respond sufficiently to available quantities of light. Several years before Hertz, a scientist had explored selenium cells. But research indicated that these cells also were too sluggish to react efficiently to the tremendous speeds of signaling.

When Baird began his independent research in 1924, no one had as yet succeeded in televising an image in half-tones on a screen.

Setting up his laboratory in a narrow attic above an artificial flower shop, he used the equipment of the rank amateur. He based his motor on an old tea chest, rotating a disc of cardboard by means of a bicycle chain he had purchased second-hand. He fitted a projection lamp into a biscuit box, and he fashioned mountings from darning needles and discarded lumber. The entire apparatus was held together by glue, string and sealing wax. To develop the high voltage needed for his experiments, he bought ordinary pocket flashlight batteries and clipped them together in rows. Whenever his technical knowledge failed him in his work, he went out to the public library and thumbed through books to "sweat out" the answer.

What Baird hoped to accomplish with his jerry-built apparatus was simple enough in theory. When a human face is televised, the variations of light from the features are transformed by photoelectric cells into variations of electric current. These currents modulate a radio wave which passes through space and is retranslated at the receiving end into electric signals. These, in turn, direct the light that builds up the original image.

According to Baird's plan, by a process of scanning, a powerful beam of light would examine the face and transmit the image point by point. At the receiving post the image would be reassembled by an exactly reverse process, recreated as a painter builds his picture, stroke by stroke.

The key to the success of the system lay in the perfecting of a sufficiently responsive photoelectric cell. For months Baird worked

perseveringly in his little studio. And one afternoon he obtained tentative results. His improvised heap of batteries, darning needles and hat boxes actually transmitted the tiny, unsteady image of a Maltese cross over a distance of a couple of yards.

In 1925 he moved up to London, and he continued his experiments in a two-room attic near Soho. The proprietor of Selfridge's London Department Store became sufficiently interested in Baird's investigations at this stage to invite him to give demonstrations of his "shadowgraphs" for customers. The circular sent out by Selfridge's to advertise the demonstrations reminded its clientele that although Baird's pictures were as yet primitive, "Edison's first phonograph announced 'Mary had a little lamb' in a way that only hearers who were 'in the secret' could understand."

The visitors at the exhibition displayed little understanding of the possibilities of Baird's apparatus. One old lady asked him if television became general whether she would be able to preserve her privacy by pulling down the blinds when she took a bath.

The greatest struggles were still ahead of the inventor. His transmission of simple shadows was not yet true television. He was still unable to send anything in the way of a living human face; no light, no shade, no actual detail. He had not bridged the gulf between the shadow and substance. In an effort to find the secret of true television, he experimented with all varieties of light-sensitive cells. He even obtained a human eye from a surgical friend and constructed a cell out of the visual purple. But the sum of his investigations was meager. The human face that appeared at the receiving end of his apparatus remained merely an oval of white. The mouth was indicated by a flickering spot of black. Nothing more.

Early backers who had put money into his apparatus in the hope that they could quickly profit on the commercial potentialities became impatient with Baird's negative results. The public

itself was convinced that Baird's machine would never transmit the image of a recognizable human face.

The young Scotchman went bankrupt. He actually denied himself the necessities of life to purchase equipment for his experiments. He was compelled to sell vital parts of his apparatus to pay his rent. Hitherto he had refused to ask his relatives in Scotland for financial assistance. But now he swallowed his pride. Several members of his family were people of means, and they contributed handsomely. They helped him form a company, Television Incorporated, and bought several thousand dollars' worth of shares.

Freed from financial headaches, Baird continued to perfect his photoelectric cell. And then on October 2, 1926, the miracle of true television occurred.

He had been using for a subject in his experiments a doll that once belonged to a ventriloquist. Hitherto "Bill's" head had been telecast upon the screen as a white blob with three black circles vaguely indicating the position of the eyes and nose. But on the above-mentioned date the unbelievable happened. Bill's face appeared as a recognizable image with shading and detail. The nose, the eyes and even the round top of the head could be clearly distinguished.

Flushed with excitement, Baird determined to try his "electric eye" on a human being. He dashed down the stairs, grabbed hold of an office boy who worked on the floor below and dragged him into his laboratory. Placing him before a battery of blinding lights he told him to sit still as he rushed over to the receiving screen. Undeniably, a lifelike face looked out at the inventor. The problem was solved.

Baird changed places with the lad and directed him to cast an eye upon the screen. And the office boy became the second living person to witness the wonder of television.

III

News of Baird's discovery traveled quickly. He gave an official demonstration to the scientists of the Royal Institution of Great Britain. An alert America sent a representative to investigate the apparatus. Baird invited Captain Oliver Hutchinson who had been an old competitor of his in the soap business to assume the financial duties of the new enterprise, Television Incorporated, leaving him free to devote his energy entirely to research.

He moved to the Motograph Building off Leicester Square. And for the first time he recruited a technical staff and employed the facilities of a high-quality laboratory. He installed his transmitter on the top floor and furnished a receiving theater a few stories below.

Soon he was able to send larger and clearer images, eliminating the excessive flickering of the early transmissions. And he reduced the amount of necessary illumination at the transmitter. Furthermore, he explored the ability of his "electric eye" to detect rays outside the range of the human eye. He developed a device which did away with visible light altogether. This new instrument responded to the infra red rays in the lower spectrum. He was able to astonish an audience by conducting a television experiment in darkness. Both the sender and the audience sat in two different rooms without illumination. And the image was transmitted by an invisible ray.

Baird gave the name "Noctovision" to this amazing process of transmission. And the apparatus which made it possible he called the "Noctoviser." In time he turned the trick of televising images by daylight, dispensing with any artificial illumination whatsoever.

Meanwhile, anxious to prove that the principles underlying the telecasting of the human face from room to room held true over large distances as well, Baird initiated a series of startling demonstrations. In May 1927, he conducted a televised trans-

mission from London to Glasgow, a distance of more than four hundred miles. It was a record for the times.

Then, after a nine months' period of intensive research at a private experimental station, he astounded the world by sending an image across the Atlantic Ocean. On February 9, 1928, a telecast of persons seated in Baird's London laboratory was picked up in Hartsdale, a suburb of New York City. The Londoners were seen clearly by the New Yorkers on a glass screen about three inches square.

The *New York Times* gave glowing credit to the "Father of Television." "Baird was the first to achieve television at all over any distance. Now he must be credited with having been the first to disembody the human form optically and electrically, flash it piecemeal at incredible speed across the ocean, and then reassemble it for American eyes. . . . All the more remarkable is Baird's achievement because he matches his inventive wits against the pooled ability and the vast resources of the great corporation physicists and engineers, thus far with dramatic success."

Baird followed his transatlantic demonstration with a telecast to a ship in midocean. The officers and passengers of the *Berengaria* viewed a transmission from Baird's studio on a portable receiver. It seemed there was no limit to the capabilities of radio's younger brother.

To convince the public that television was rapidly approaching the stage at which it could be employed commercially, Baird requested the British Broadcasting Corporation to incorporate experimental television programs into its regular radio schedules. But he found it impossible at first to hammer home to B.B.C. the fact that television had "arrived." The negotiations led to a sharp controversy. And for a time Baird was compelled to continue experiments privately from his own studio. However, in September 1929, the B.B.C. was at last induced to inaugurate a half hour broadcast over one of its own transmitters.

The concept of television for the millions was gradually taking

root. Still, there were technical difficulties to be overcome. One of the chief obstacles to mass production of television sets was the problem of synchronizing the scanning of the transmitter with the receiver. Baird finally solved it with a device for automatic self-synchronization.

In the meantime he continued to develop miraculous by-products. He devised, for instance, "Phonovision." This was based on the interesting fact that the electric impulses transmitted in television can be heard as sounds by anyone tuning in upon them. These image sounds—a rapid and high-pitched "me-me-me"—may be played into a recording phonograph and stored away for future use just as any other sound. As a result of Baird's invention it was possible to record living scenes in wax to be re-televised anytime.

Baird also transmitted regular "talking" films by television. "Tele-Talkies" he called them. In addition he enlarged his receiving screen to enable cinema audiences to receive his telecasts. Screens were installed for demonstrations in moving picture houses in London, Paris, Berlin and Stockholm. For several weeks at a time television broadcasts were given as part of the regular film programs.

But the chief event that dramatized to the people the revolutionary qualities of the new medium was Baird's broadcast of the Derby on June 3, 1931. The following year he made an even more spectacular transmission of Great Britain's leading racing event. He focused his "electric eye" upon the turf at Epsom and televised the races for an audience of five thousand sitting fifteen miles away in a London cinema. When the meet was over, the inventor who had made the marvel possible stepped upon the stage and received a greater ovation than the winning thoroughbred.

Baird made his first trip to the United States in September, 1931, and he spoke by radio to the American people of the bright future of the "electric eye." "Television is only in its infancy," he

declared, "and big developments are pending. The television images which have been seen by the general public are no criterion of what has been achieved in the laboratories. Our work is now to simplify and cheapen our present laboratory apparatus so that it can be made available to the man in the street. The problem of television is solved. What remains to be done is entirely a matter of technical and commercial development. . . . I myself look forward to seeing, in the not too distant future, . . . the home 'televisor' become as common as the home radio today."

IV

WEALTHY AND SUCCESSFUL, Baird remained as unpretentious as ever. His huge shock of hair and spectacles gave him more the appearance of a professor of mathematical philosophy than of a hard-headed inventor who dealt with the tangible magic of the present. Although he was assisted by a team of able technicians, he paced his laboratory with the rapid desperate movements of a man who wishes to reach the millennium before lunchtime.

During his trip to America in the fall of 1931, he married Cecilia Albu, a London concert pianist and a niece of the head of a large gold-mining syndicate in South Africa. Two children were born of the marriage.

Baird was definitely a prophet with honor. A plaque was put over the address at which he had begun his experiments on television in 1924. One more garret was thereby memorialized for future tourists.

Scotland, too, commemorated her son of the manse. A medal was struck especially for him and presented to him in Glasgow.

In 1936 the first private television receiving sets were manufactured for the British public. And that same year television programs were incorporated as a permanent feature of the British Broadcasting Corporation. Studios were established at the Alexandra Palace in the northern outskirts of London, marking the

world's first high-definition television service. A year later the "electric eye" scored its most scintillating scoop. The coronation ceremonies of King George VI and Queen Elizabeth were wired into private parlors.

With the outbreak of the war against Hitler in 1939, television broadcasts were cancelled. Its resources were enlisted in the service of radar to detect enemy ships and planes. But Baird managed to continue private experiments. And during the war years he opened up fields which have not as yet been exploited commercially.

He commenced investigations in the transmission of color. Utilizing the principle that all colors seen by the eye can be reproduced by various combinations of three primary ones, red, blue and yellow, he experimented with a revolving disc, which transmitted in sequence first the red areas of an image, then the blue and finally the yellow. These were received on the screen in such a rapid succession that they blended together to form pictures of every natural shade.

But by 1944 Baird dispensed with the revolving disc and televised color directly by means of the cathode ray tube. He called his instrument the "Telechrome."

In addition to his research in color, he developed stereoscopic vision—the telecasting of solid three-dimensional objects instead of flat images. He applied an old principle. He succeeded in sending out two images, one being a picture of the scene viewed by the right eye, and the other by the left. An optical device in the receiver enabled the right eye to see only the right image, and the left eye to see only the left. This is an approximation of what takes place in natural vision.

Baird, however, was compelled to part from his advanced research while it was still a laboratory novelty. He died before the benefits of "Telechrome" and stereoscopic vision could be realized by the general public.

This hard-working son of a minister who overcame numerous sieges of ill-health as a young man and who survived the bomb-

ing of his London home during the war, succumbed suddenly to influenza on June 14, 1946, at the age of fifty-eight.

He passed away at the height of his career too soon to witness every last one of his predictions come true.

V

Other countries, notably the United States, have made vast strides in television over the last decade. The new developments in electronics have completely overhauled early systems of television. Baird's mechanical device for scanning, for instance, has been replaced by Farnsworth's "image dissector" and by Zworykin's kinescope. In order to transmit flickerless images with a clearness comparable to the movies, cathode ray tubes have been installed in receivers. The science of electronics has made possible the telecasting of pictures of a high frequency and detail far beyond the achievement of Baird's first demonstrations.

In 1939 regular television broadcasts were inaugurated in the United States. That year the first American prizefight, football and baseball games were televised. And receiving sets were sold to the public.

At present an ever-growing audience of Americans and a proportionately large public in Great Britain, to mention only two countries, tune in regularly on sports events, news broadcasts and entertainment. The future of television is challenging, to say the least. And it has been made possible in large measure through the genius of a Scotchman who tinkered with a gimcracky gadget as the result of a physical breakdown.

God said, "Let there be light!" And along came John Logie Baird to give the world his "magic eye." He presented human beings with a medium for annihilating vast distances and for dwelling in close visual intimacy with one another. Television may well be the link which will finally bind the community of men into a community of friends.